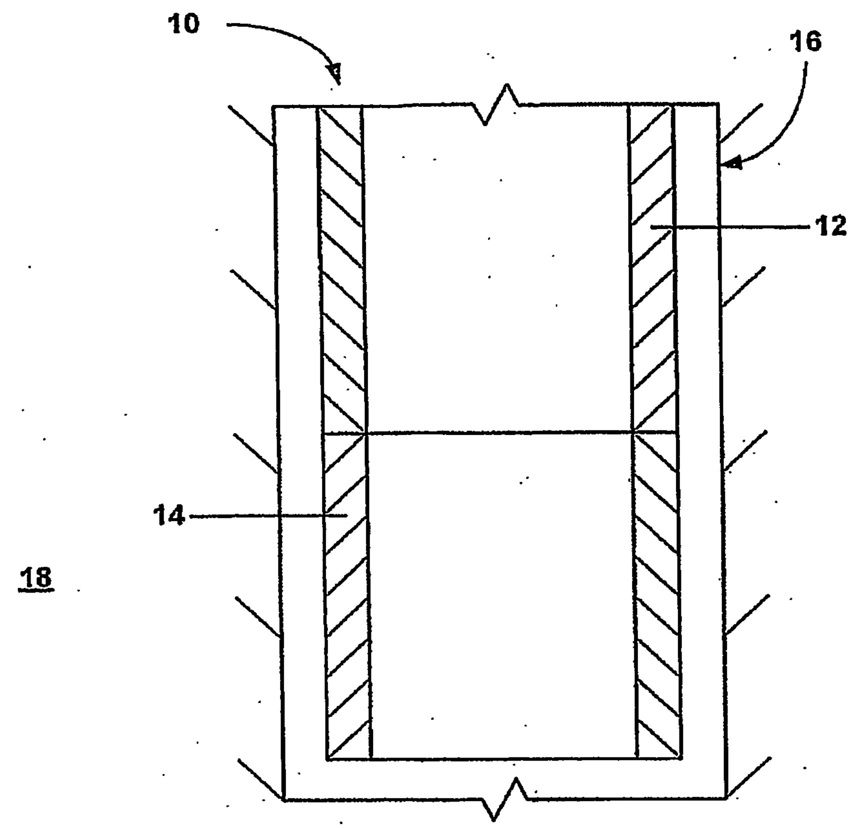


FIG. 1

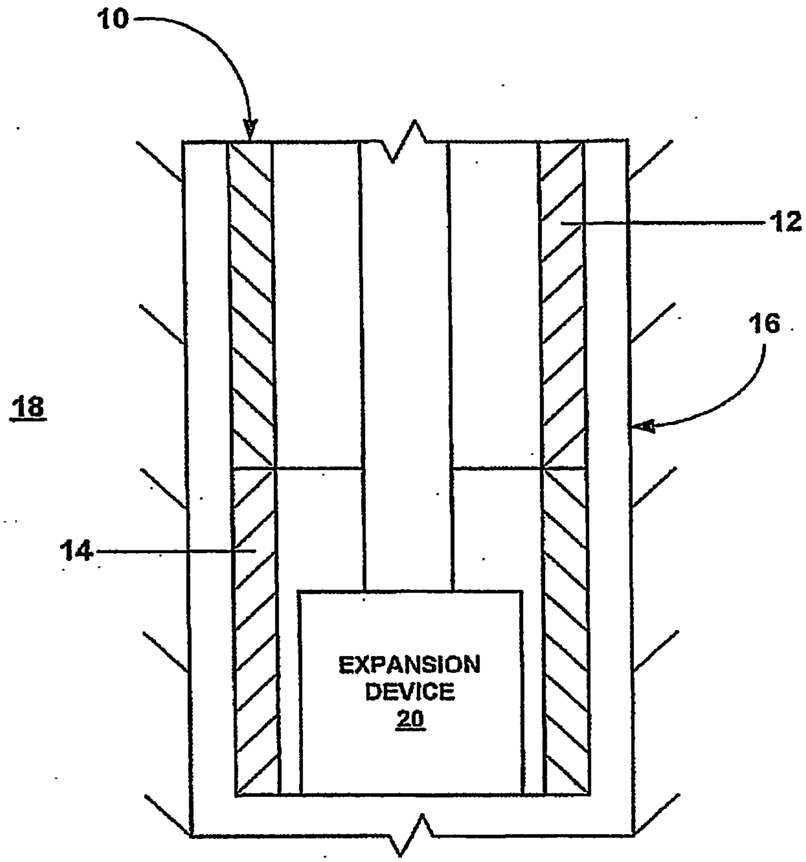


FIG. 2

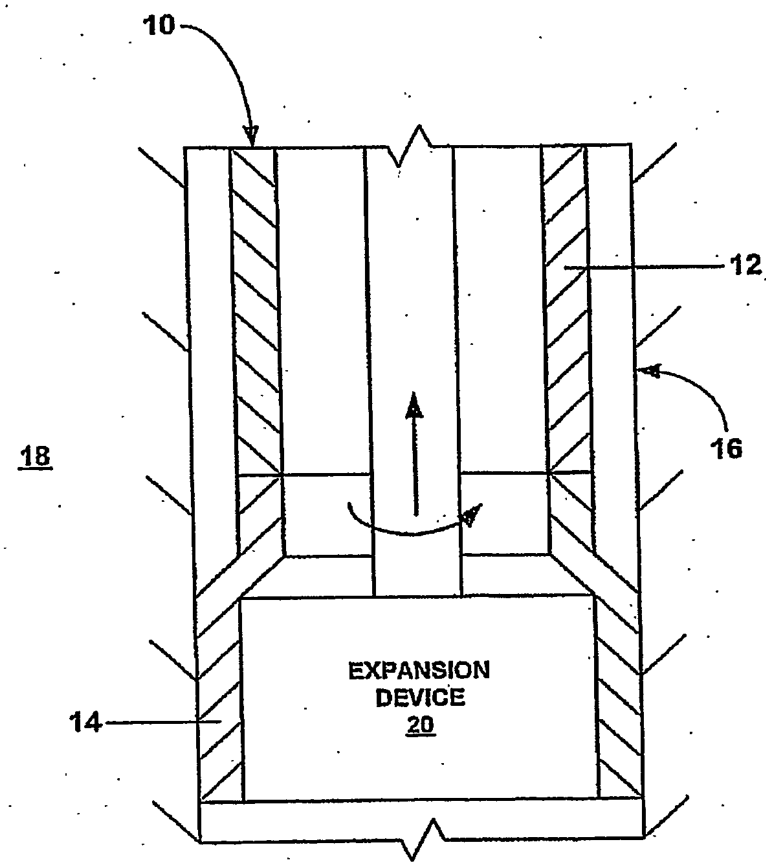


FIG. 3

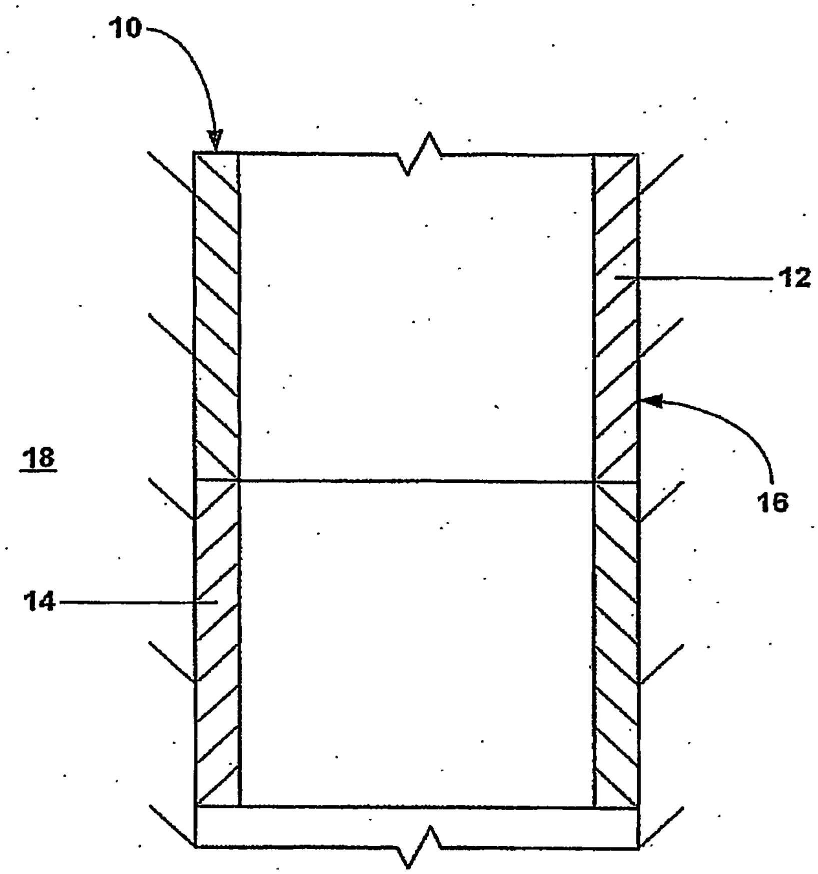


FIG. 4

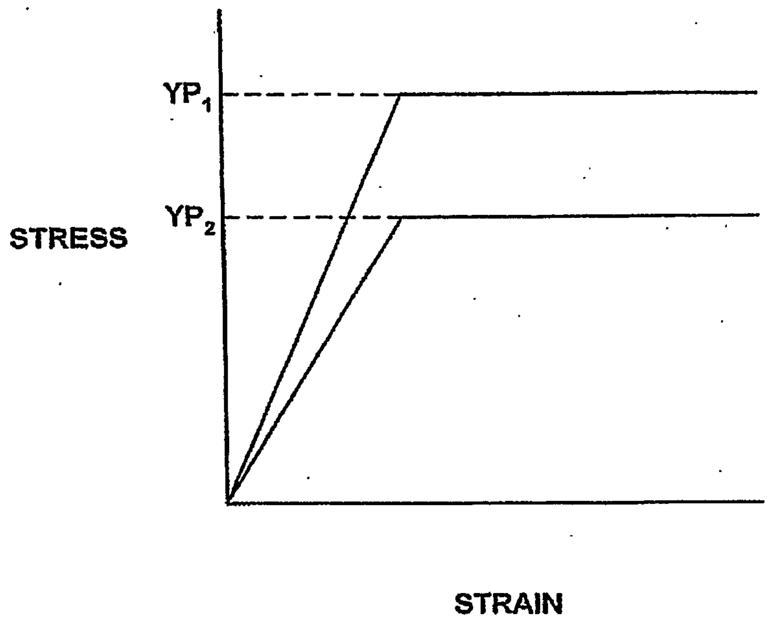

YP$_1$
YP$_2$
STRESS
STRAIN

FIG. 5

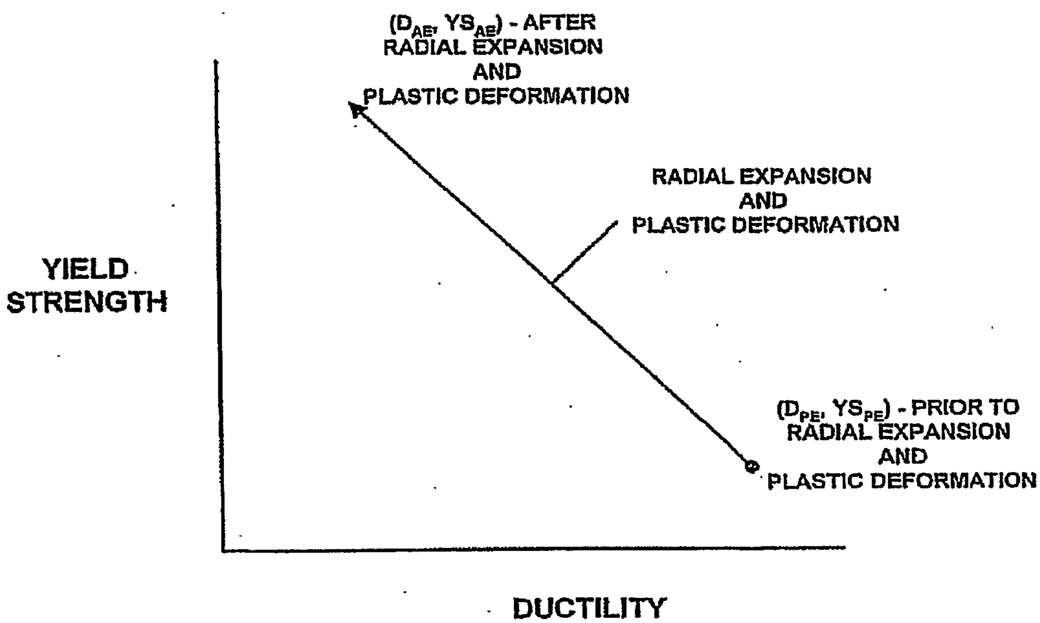

(D_{AE}, YS_{AE}) - AFTER RADIAL EXPANSION AND PLASTIC DEFORMATION
RADIAL EXPANSION AND PLASTIC DEFORMATION
YIELD STRENGTH
(D_{PE}, YS_{PE}) - PRIOR TO RADIAL EXPANSION AND PLASTIC DEFORMATION
DUCTILITY

FIG. 6

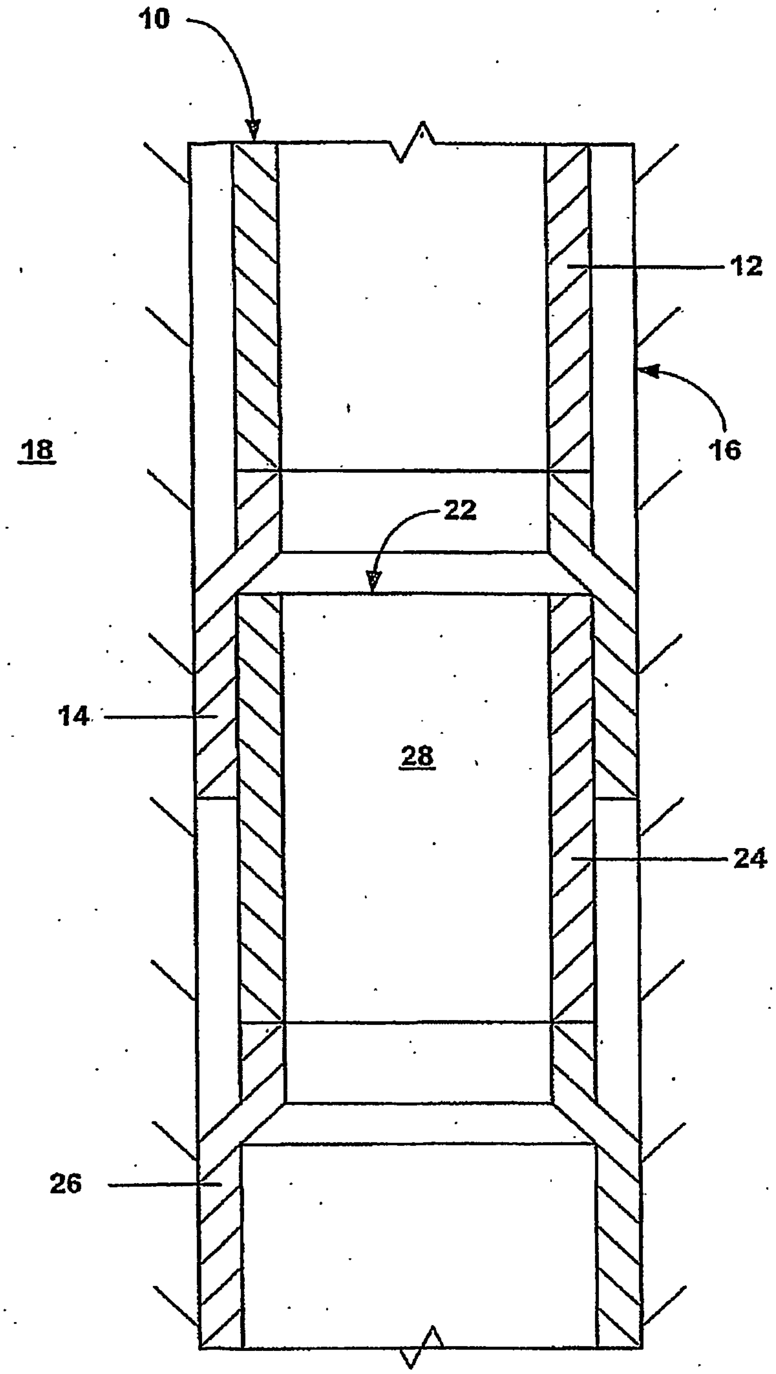


FIG. 7

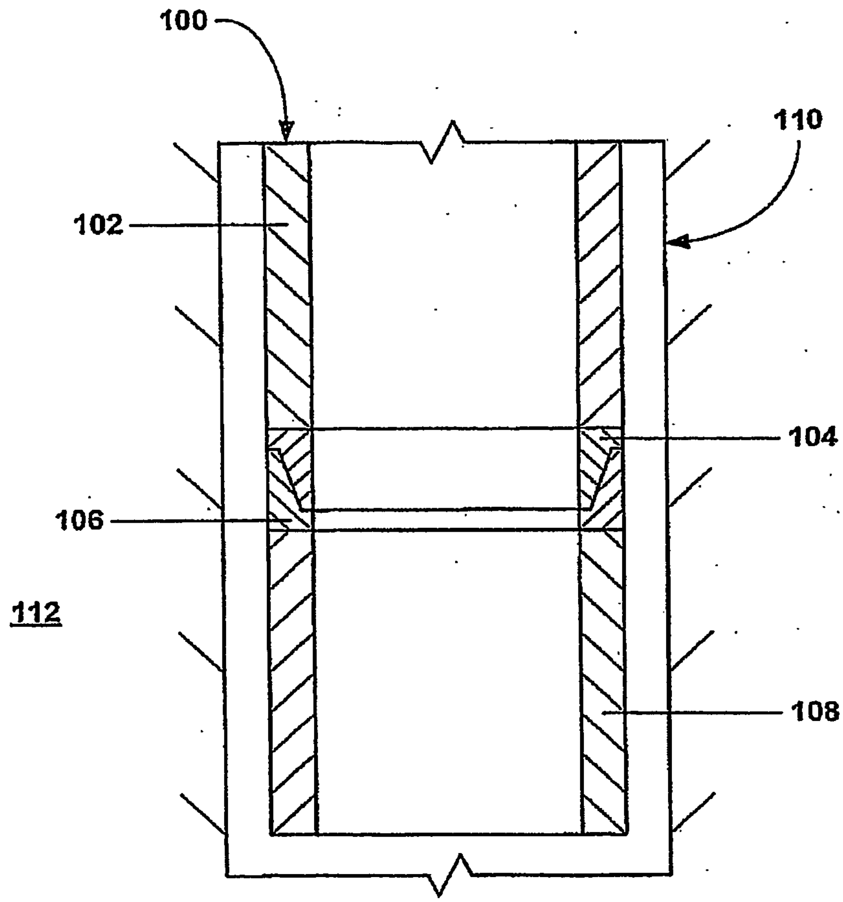


FIG. 8

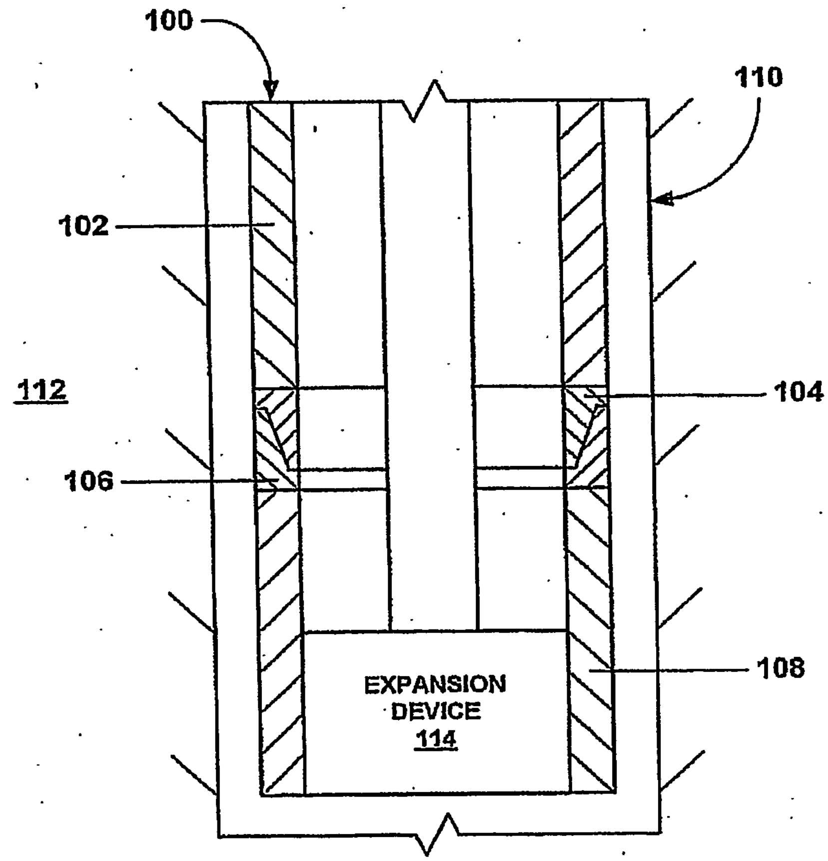


FIG. 9

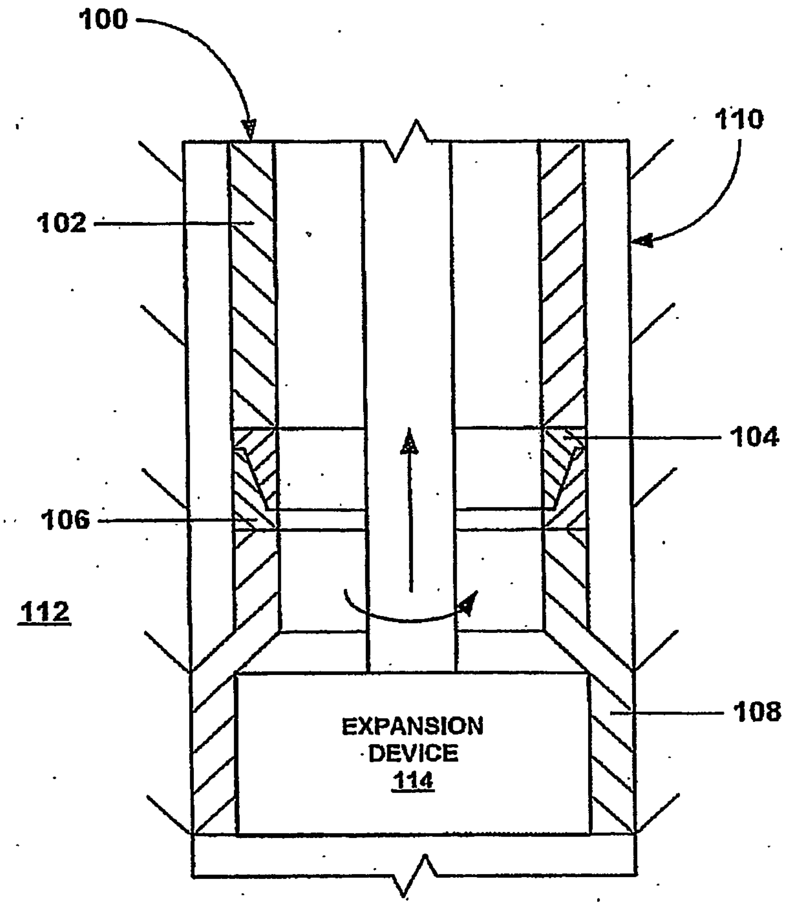


FIG. 10

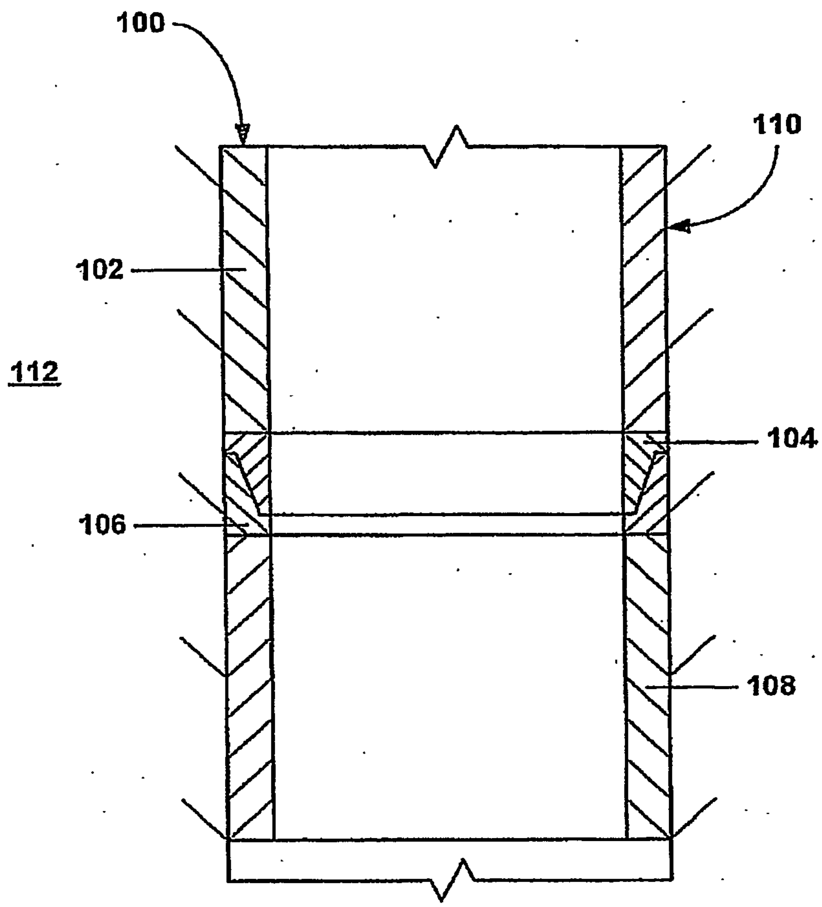


FIG. 11

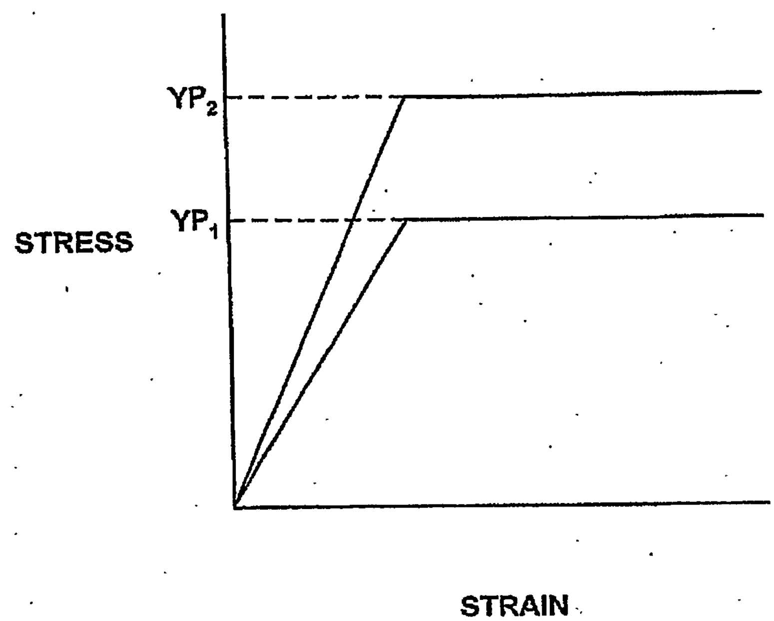

YP2
YP1
STRESS
STRAIN

FIG. 12

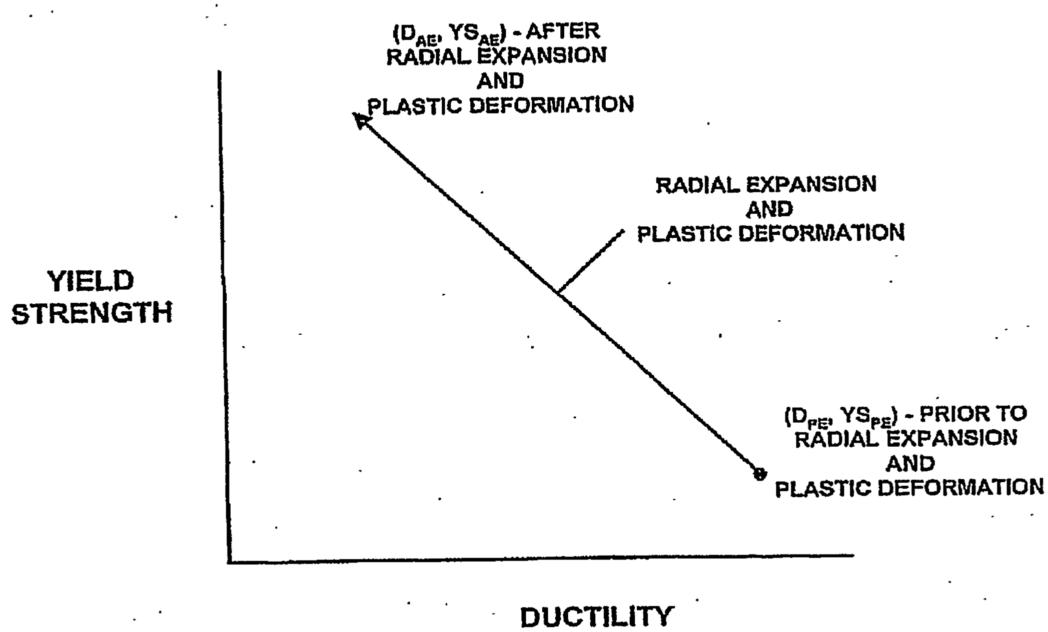

(DAE, YSAE) - AFTER RADIAL EXPANSION AND PLASTIC DEFORMATION
RADIAL EXPANSION AND PLASTIC DEFORMATION
YIELD STRENGTH
(DPE, YSPE) - PRIOR TO RADIAL EXPANSION AND PLASTIC DEFORMATION
DUCTILITY

FIG. 13

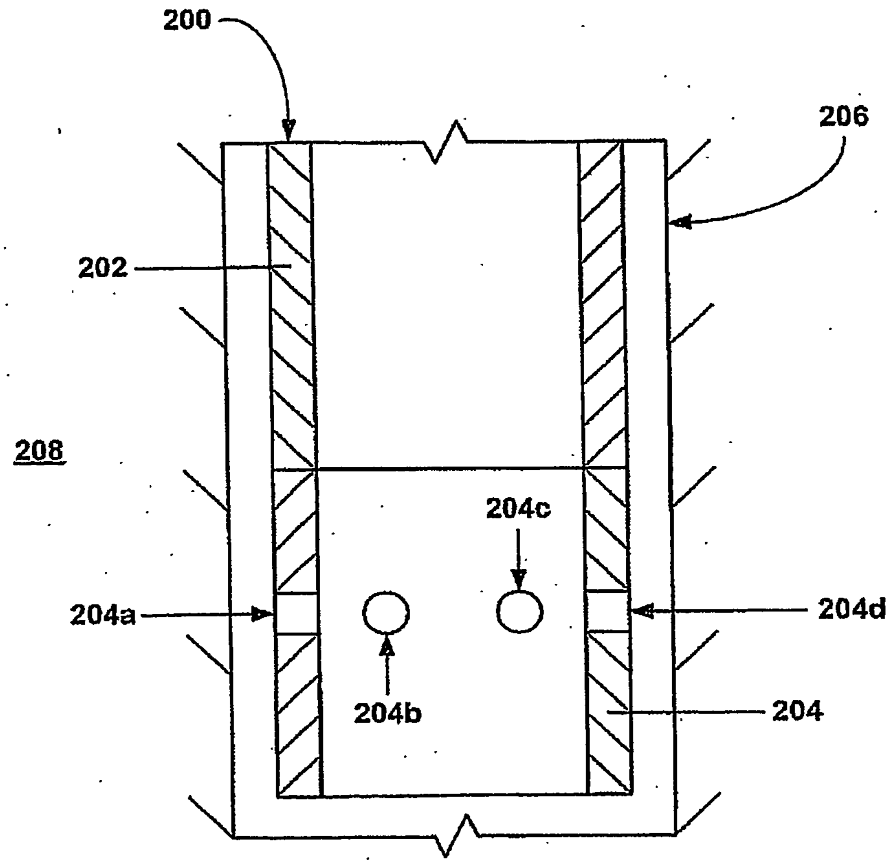


FIG. 14

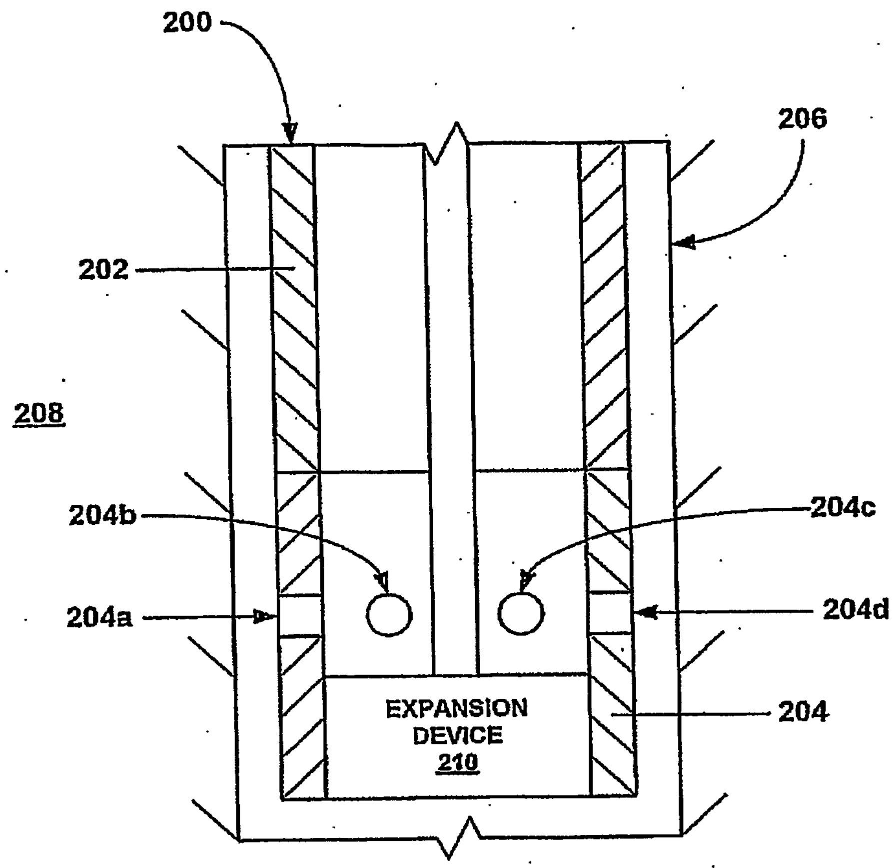


FIG. 15

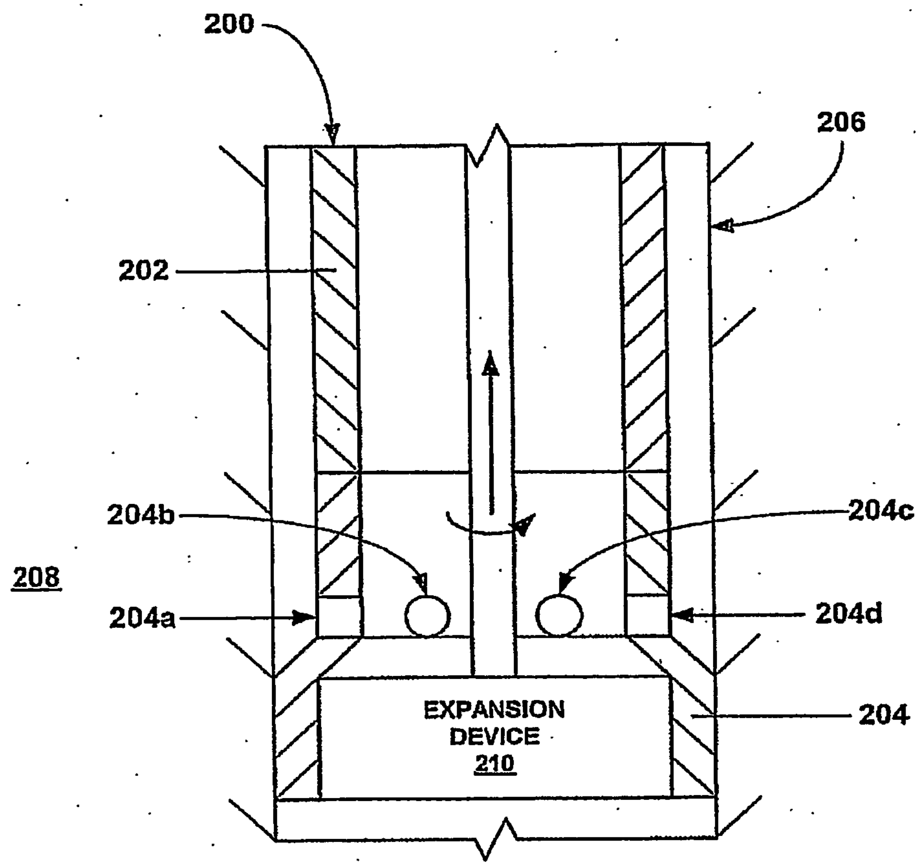


FIG. 16

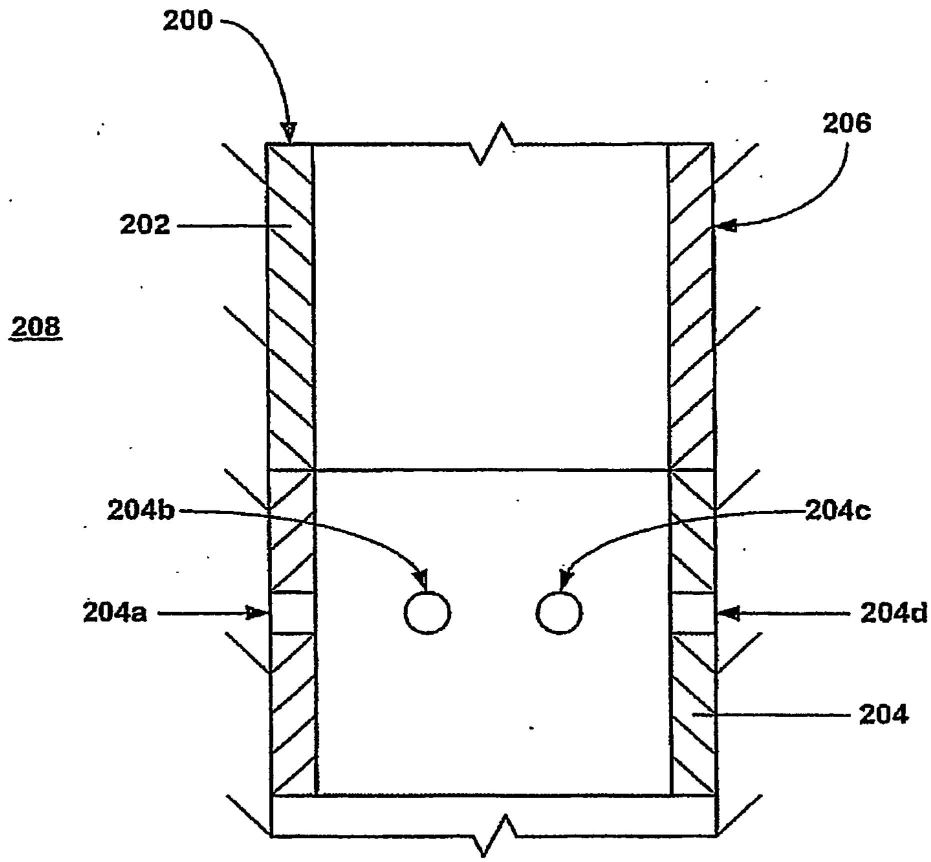


FIG. 17

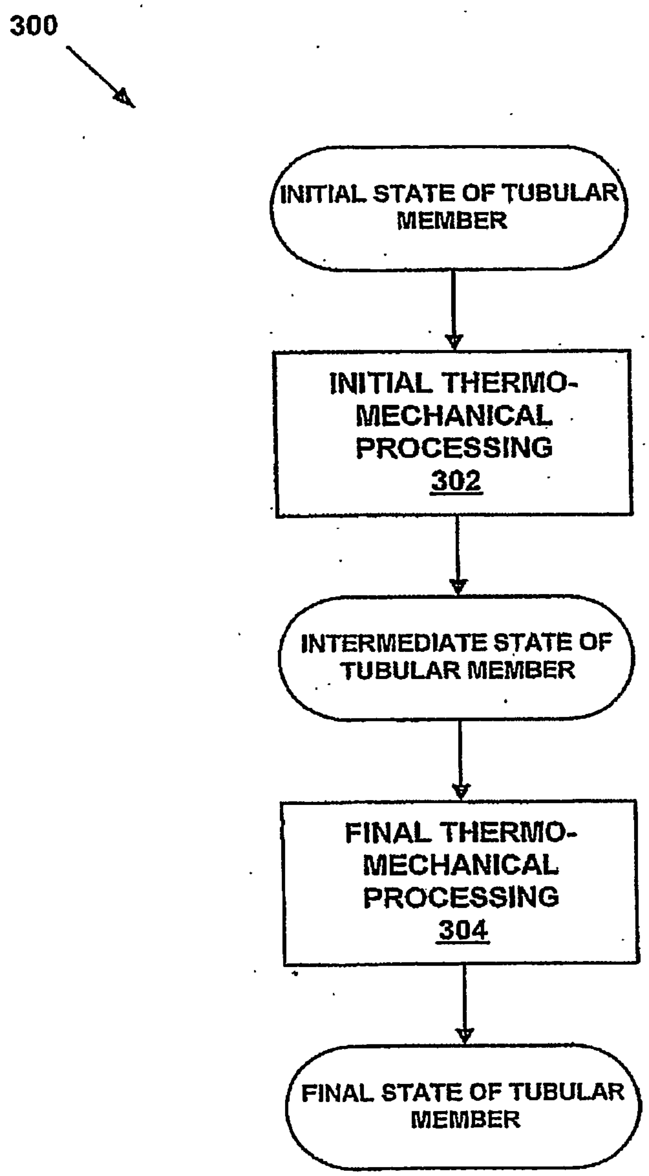

300
INITIAL STATE OF TUBULAR MEMBER
INITIAL THERMO-MECHANICAL PROCESSING 302
INTERMEDIATE STATE OF TUBULAR MEMBER
FINAL THERMO-MECHANICAL PROCESSING 304
FINAL STATE OF TUBULAR MEMBER

Fig. 18

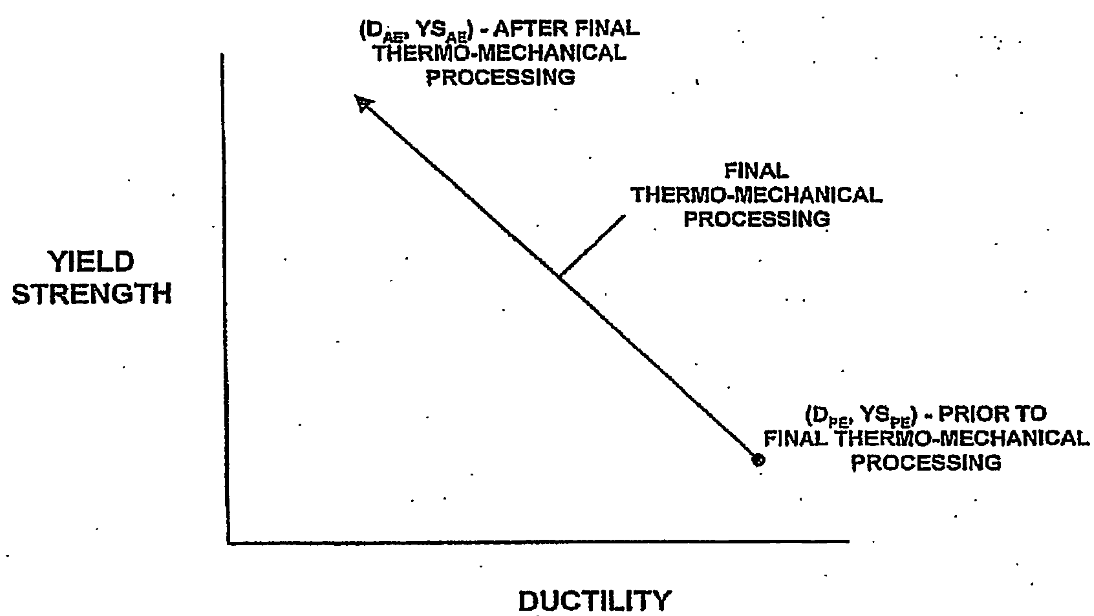

(D_{AE}, YS_{AE}) - AFTER FINAL THERMO-MECHANICAL PROCESSING
FINAL THERMO-MECHANICAL PROCESSING
YIELD STRENGTH
(D_{PE}, YS_{PE}) - PRIOR TO FINAL THERMO-MECHANICAL PROCESSING
DUCTILITY

FIG. 19

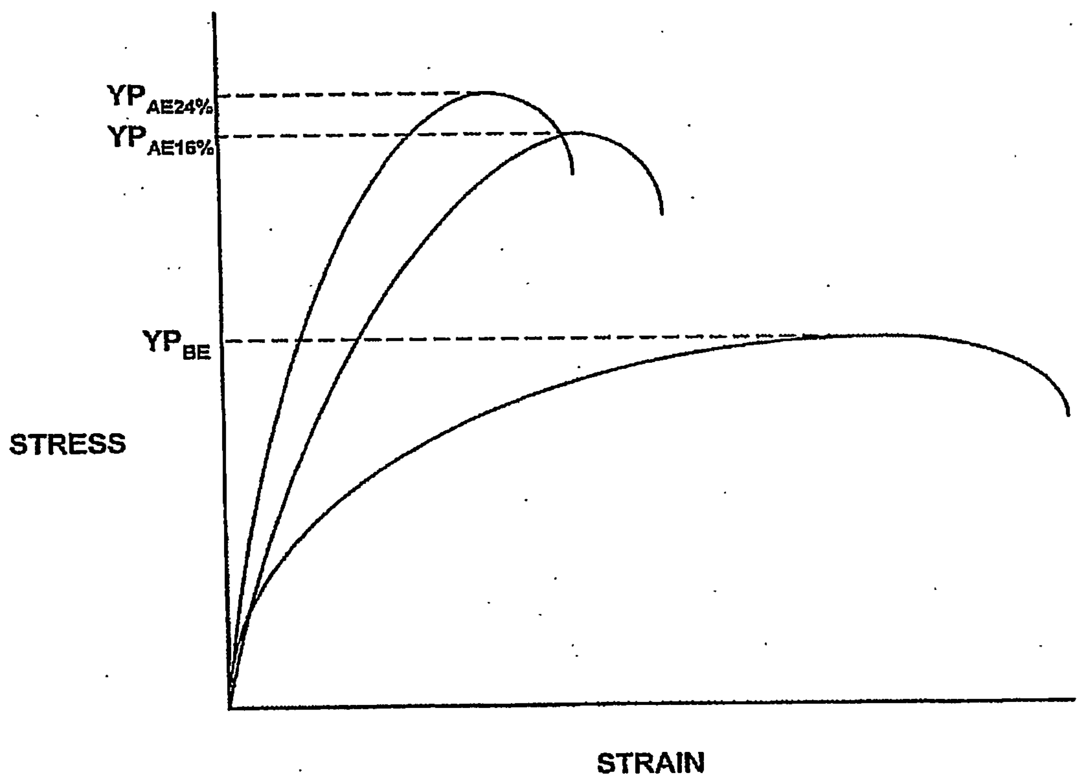


FIG. 20

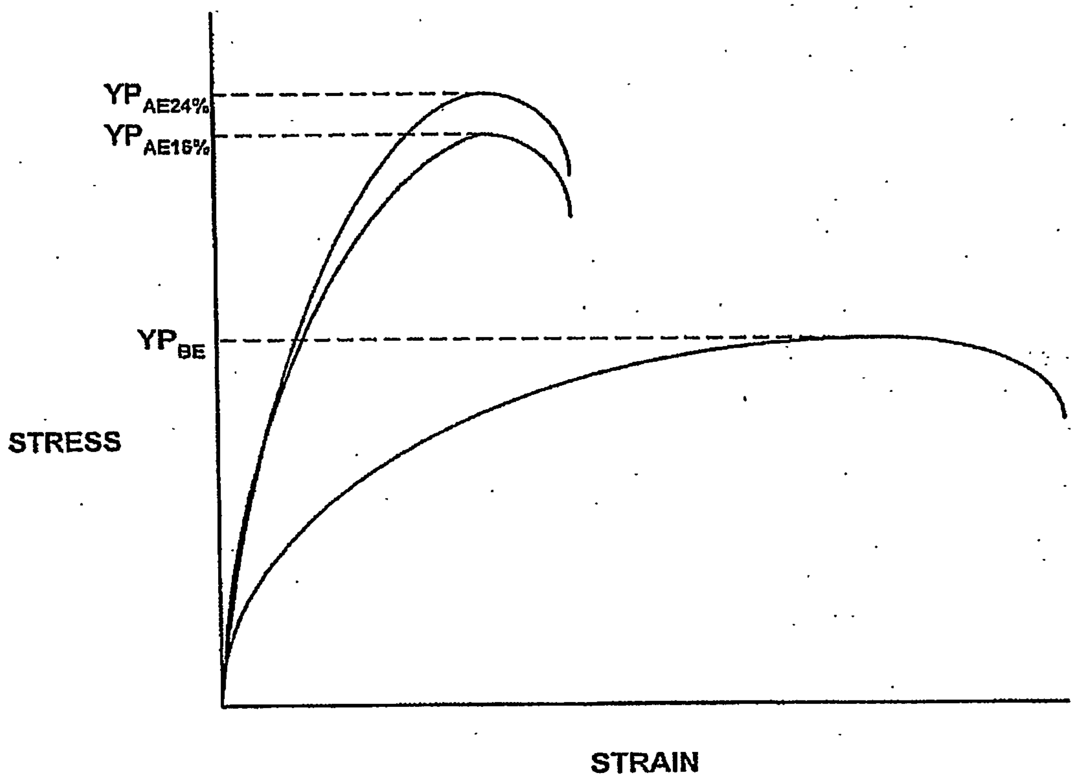


FIG. 21

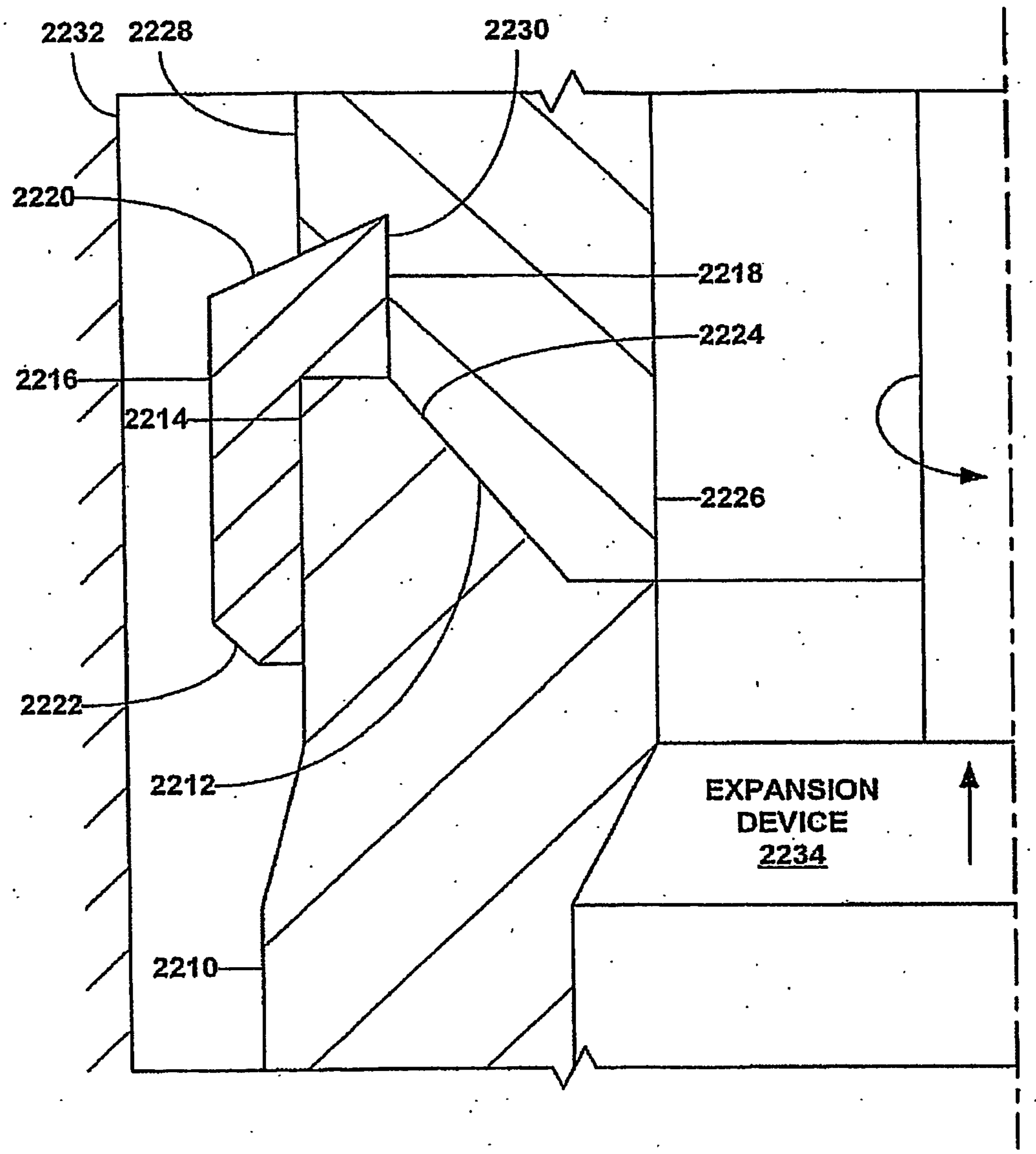

2232
2228
2230
2220
2218
2224
2216
2214
2226
2222
2212
EXPANSION
DEVICE
2234
2210

FIG. 22

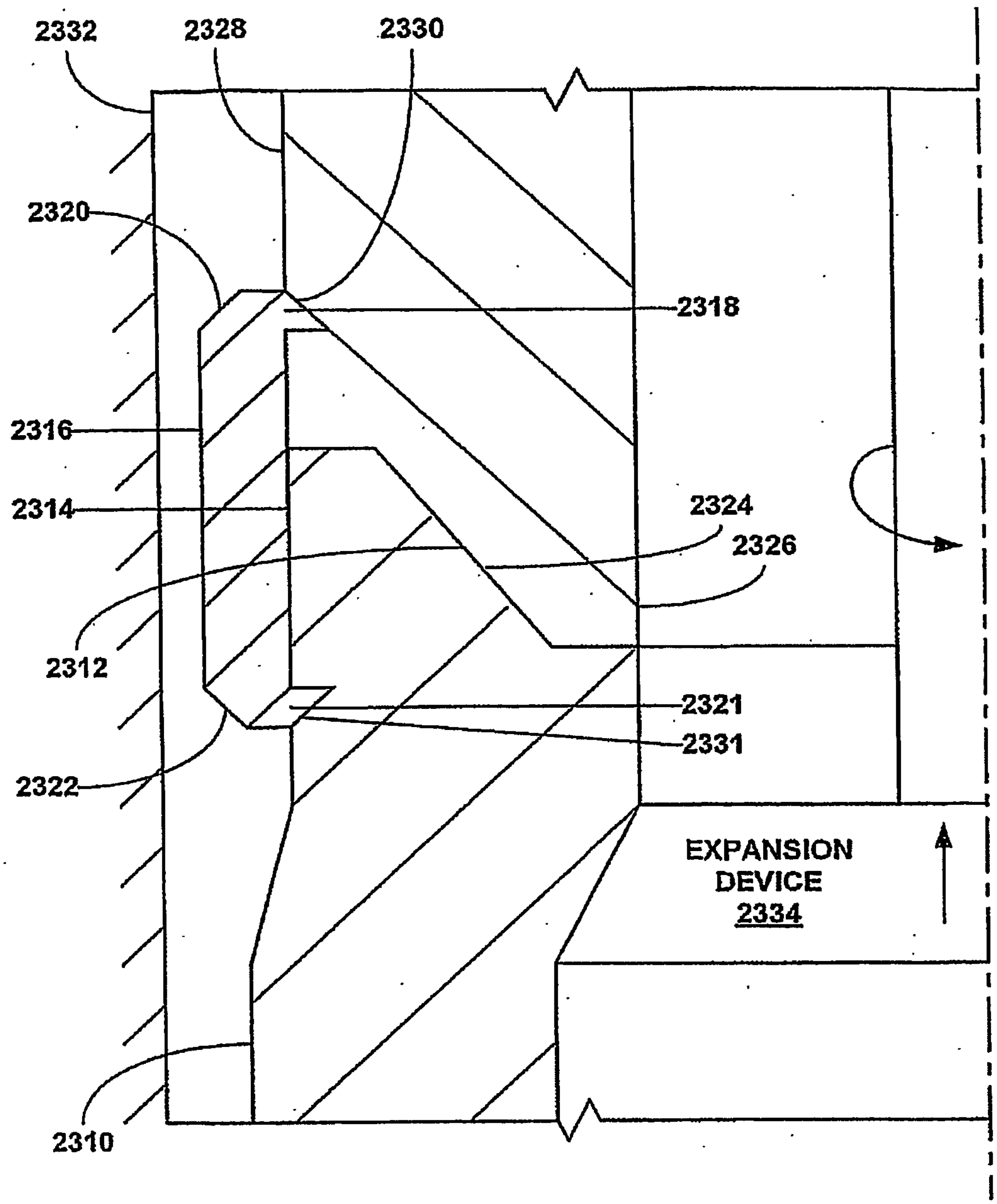

2332
2328
2330
2320
2318
2316
2314
2324
2326
2312
2321
2331
2322
EXPANSION
DEVICE
2334
2310

FIG. 23

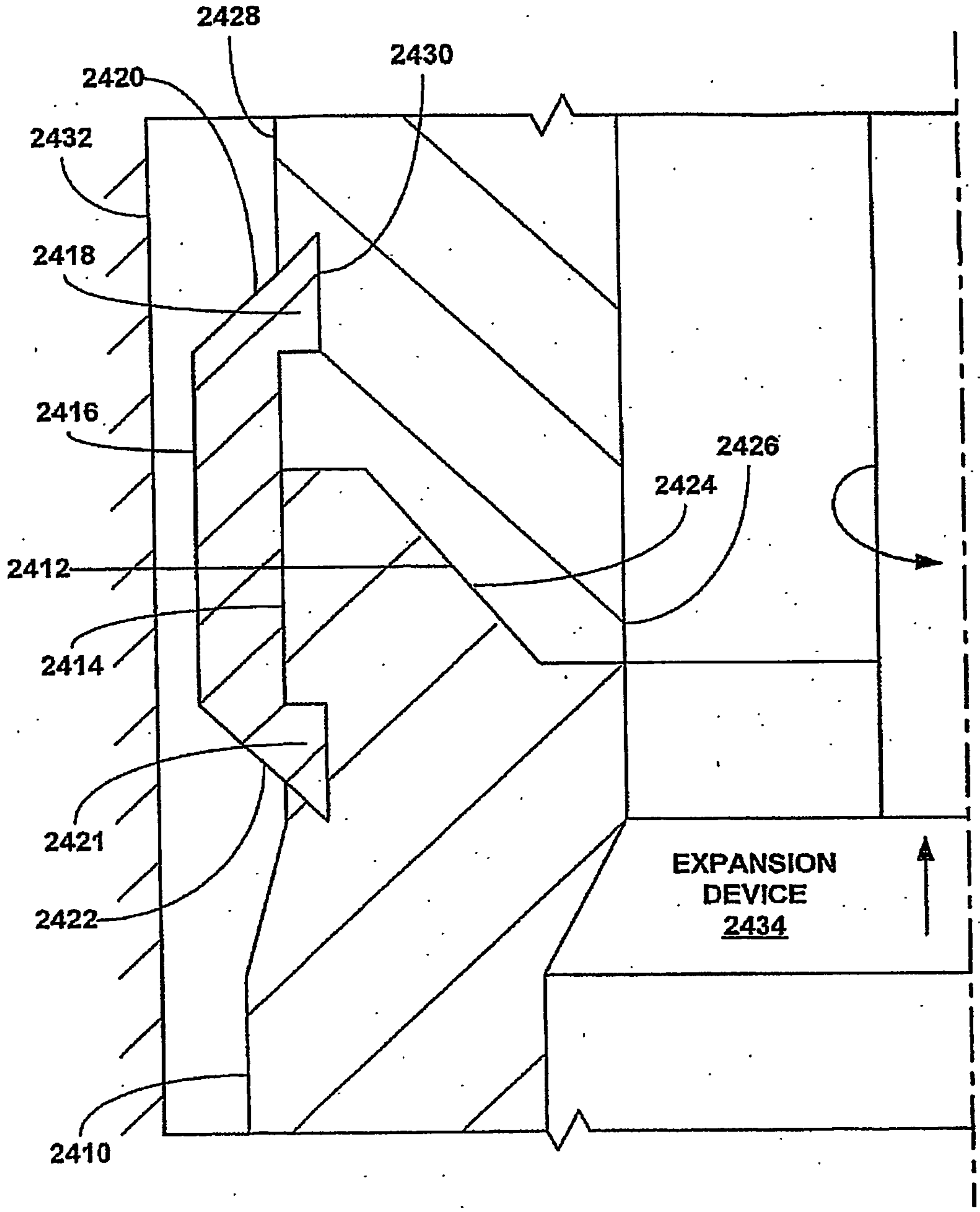

2428
2430
2420
2432
2418
2416
2426
2424
2412
2414
2421
2422
2410
EXPANSION
DEVICE
2434

FIG. 24

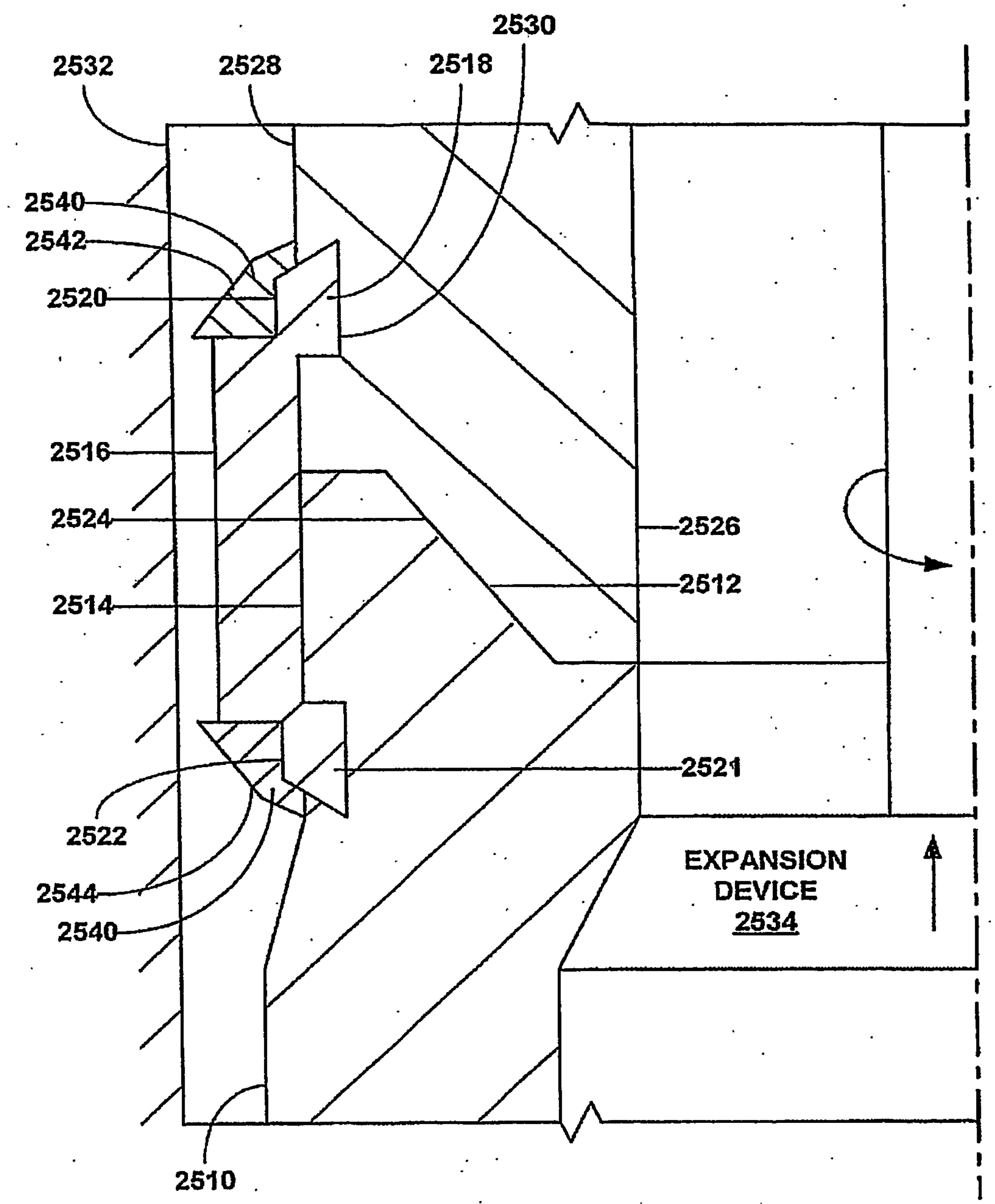

2530
2532
2528
2518
2540
2542
2520
2516
2524
2526
2512
2514
2521
2522
EXPANSION
DEVICE
2534
2544
2540
2510

FIG. 25

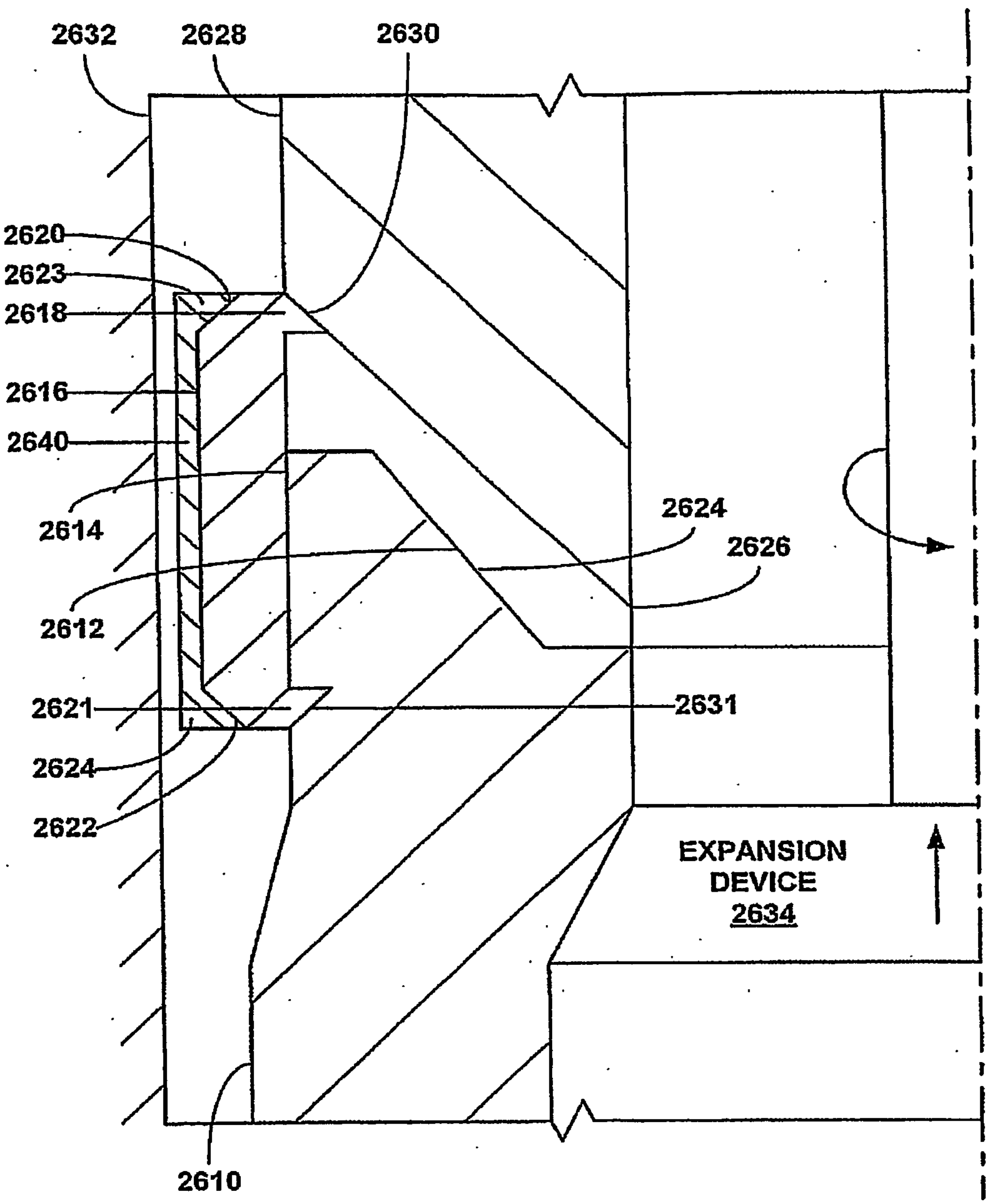
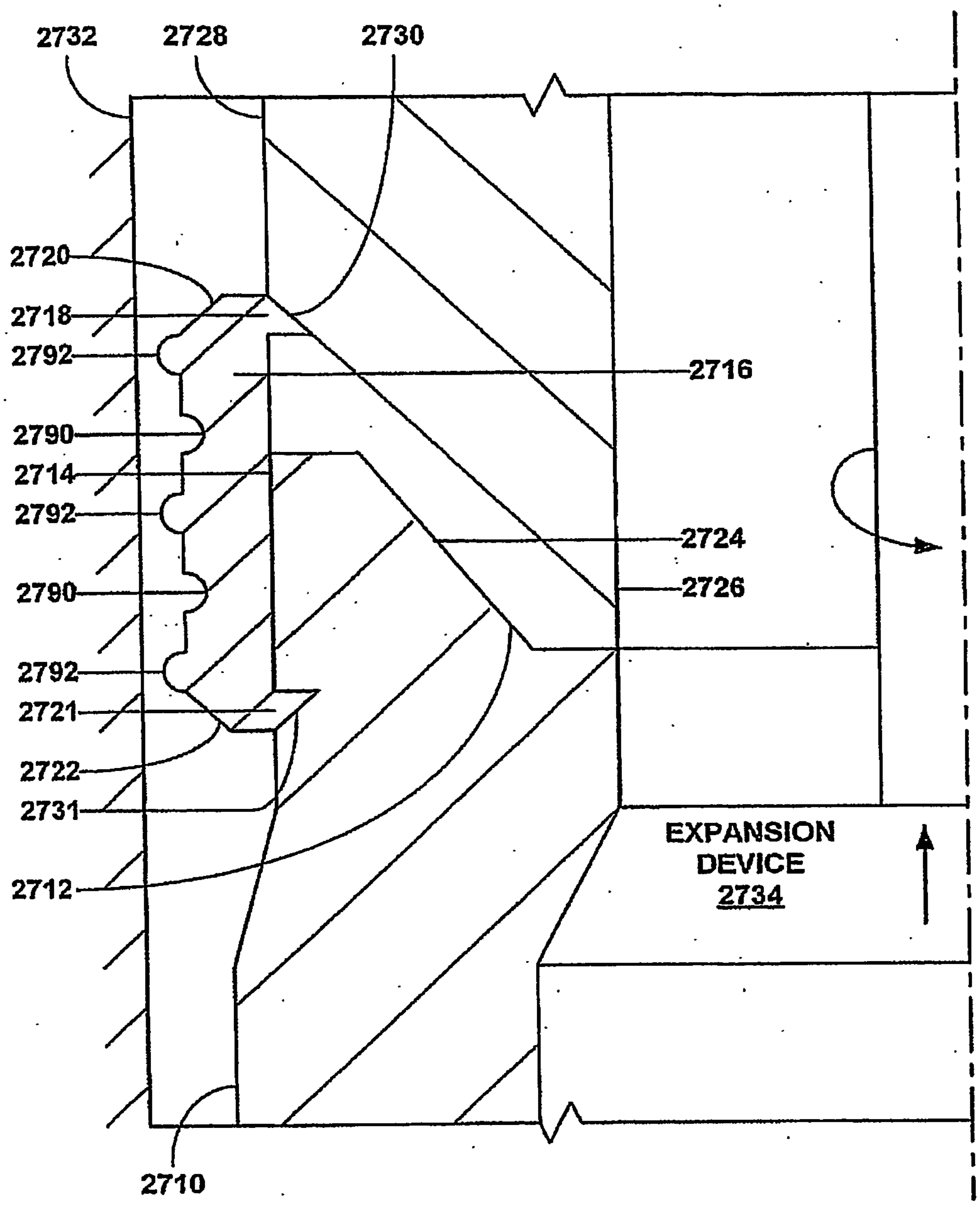

2632
2628
2630
2620
2623
2618
2616
2640
2614
2624
2626
2612
2621
2631
2624
2622
EXPANSION
DEVICE
2634
2610

FIG. 26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2728
2730
2720
2718
2792
2716
2790
2714
2792
2724
2790
2726
2792
2721
2722
2731
2712
EXPANSION
DEVICE
2734
2710

FIG. 27

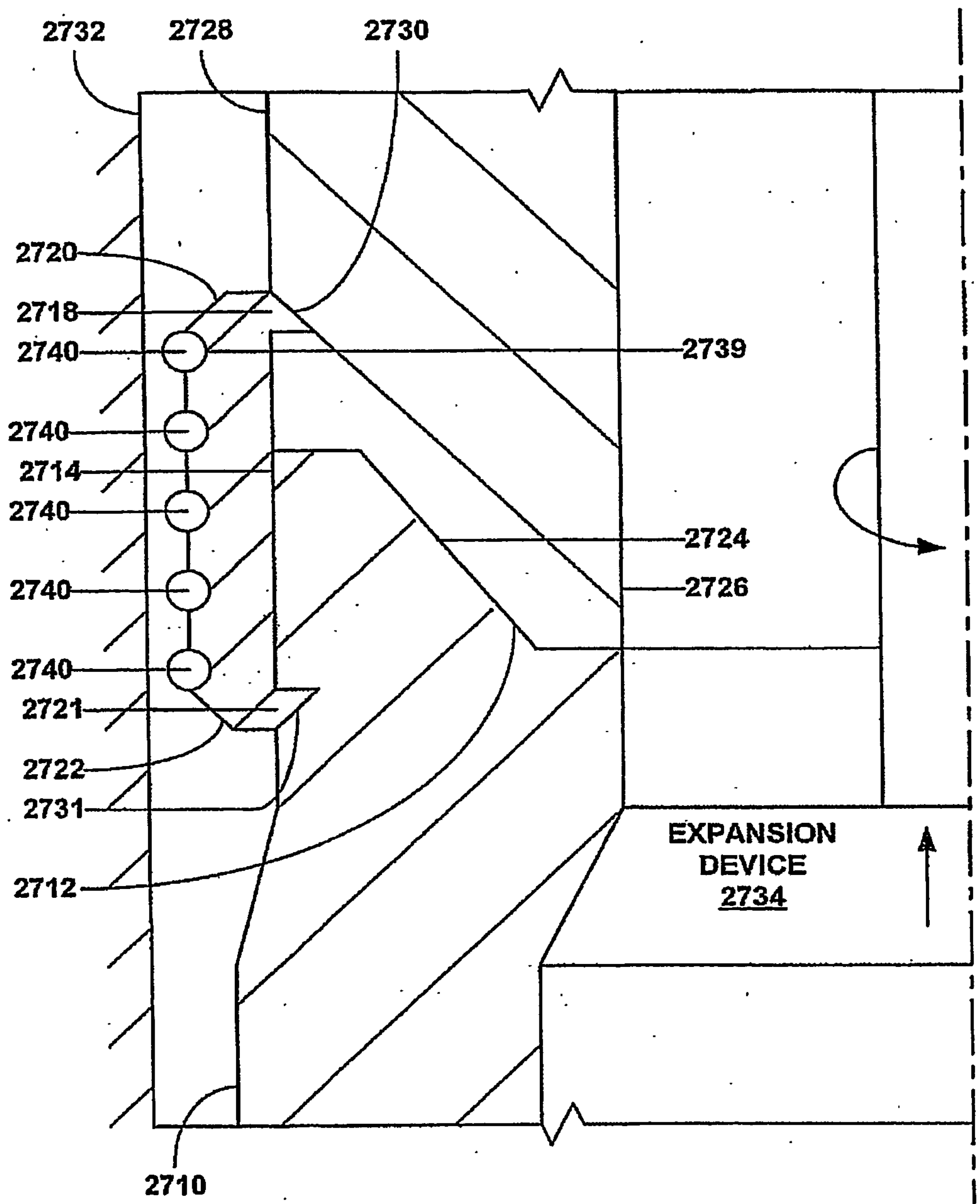

2732
2728
2730
2720
2718
2740
2739
2740
2714
2740
2724
2740
2726
2740
2721
2722
2731
EXPANSION
DEVICE
2734
2712
2710

FIG. 28

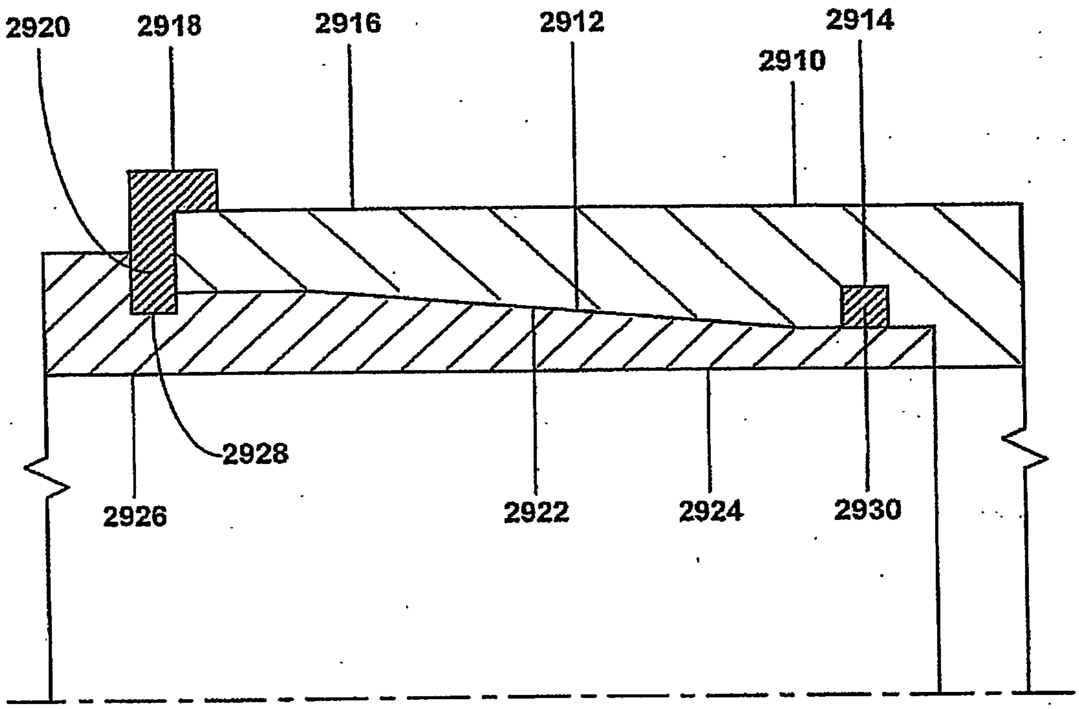


FIG. 29

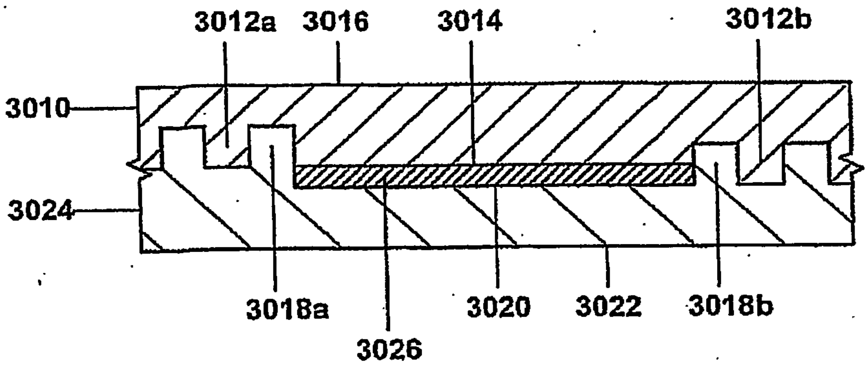


FIG. 30a

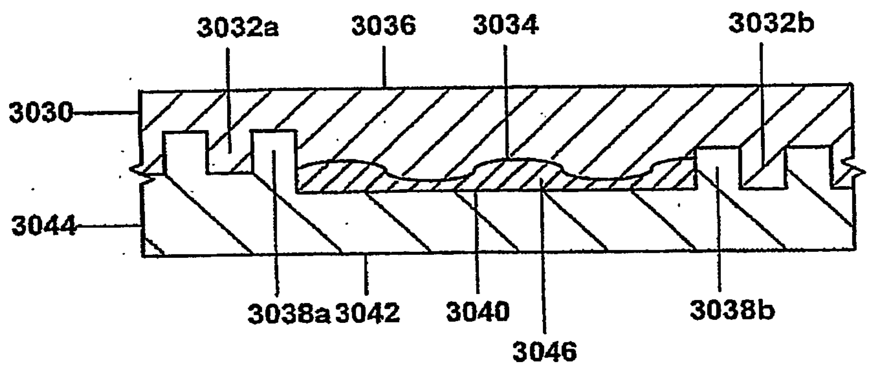


FIG. 30b

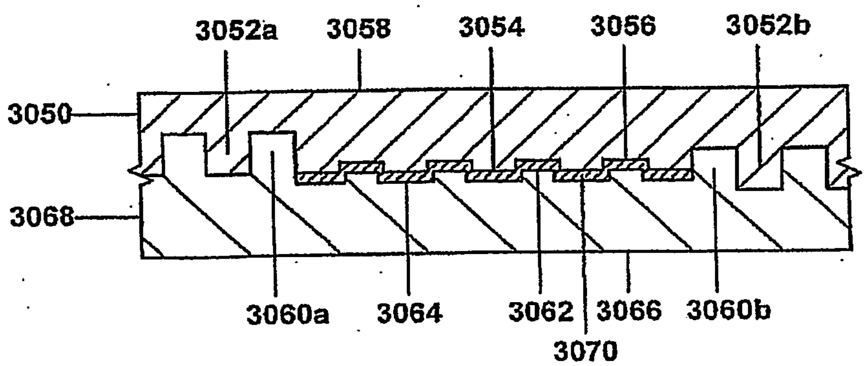


FIG. 30c

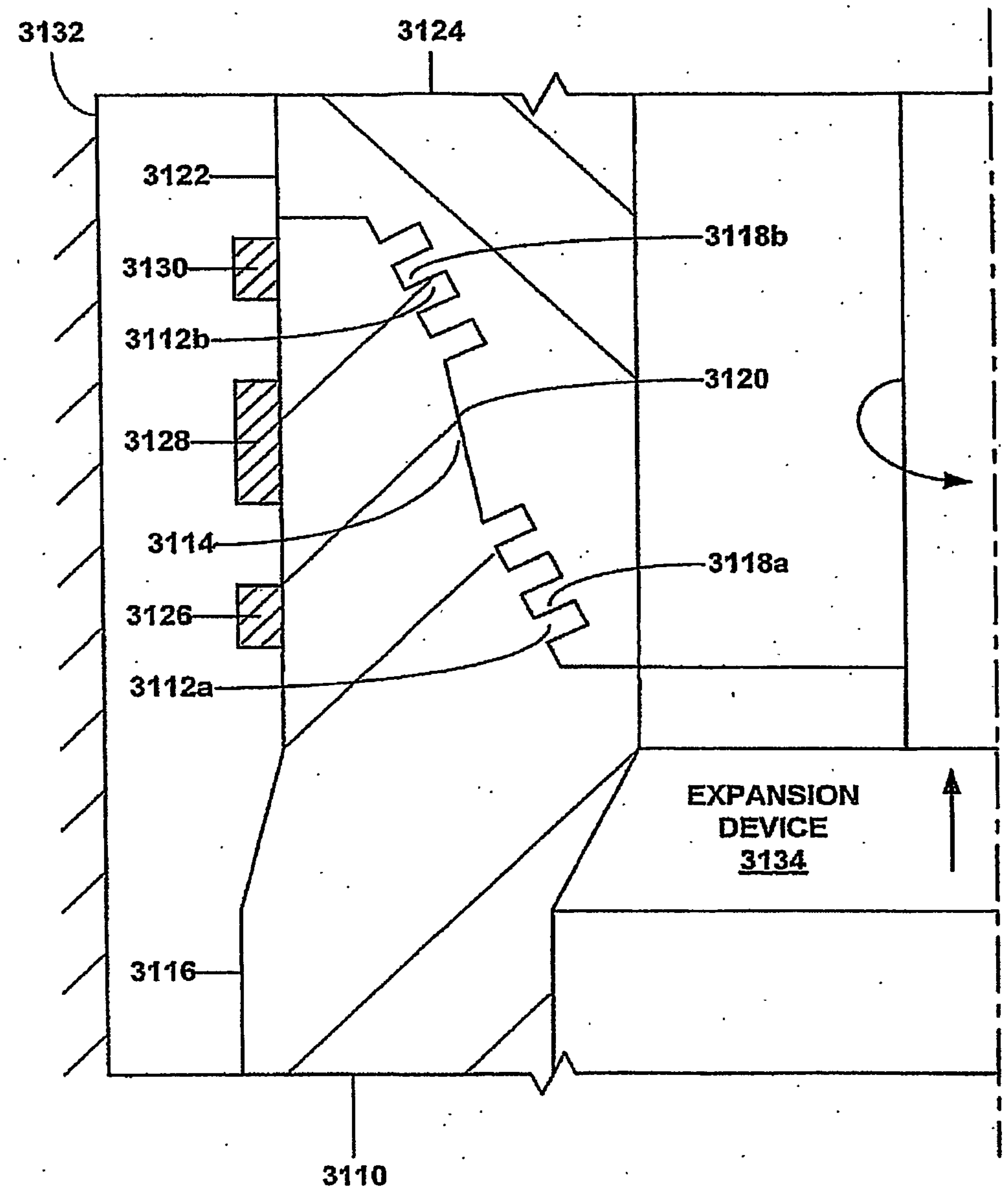

3132
3124
3122
3130
3112b
3128
3114
3126
3112a
3116
3118b
3120
3118a
EXPANSION
DEVICE
3134
3110

FIG. 31

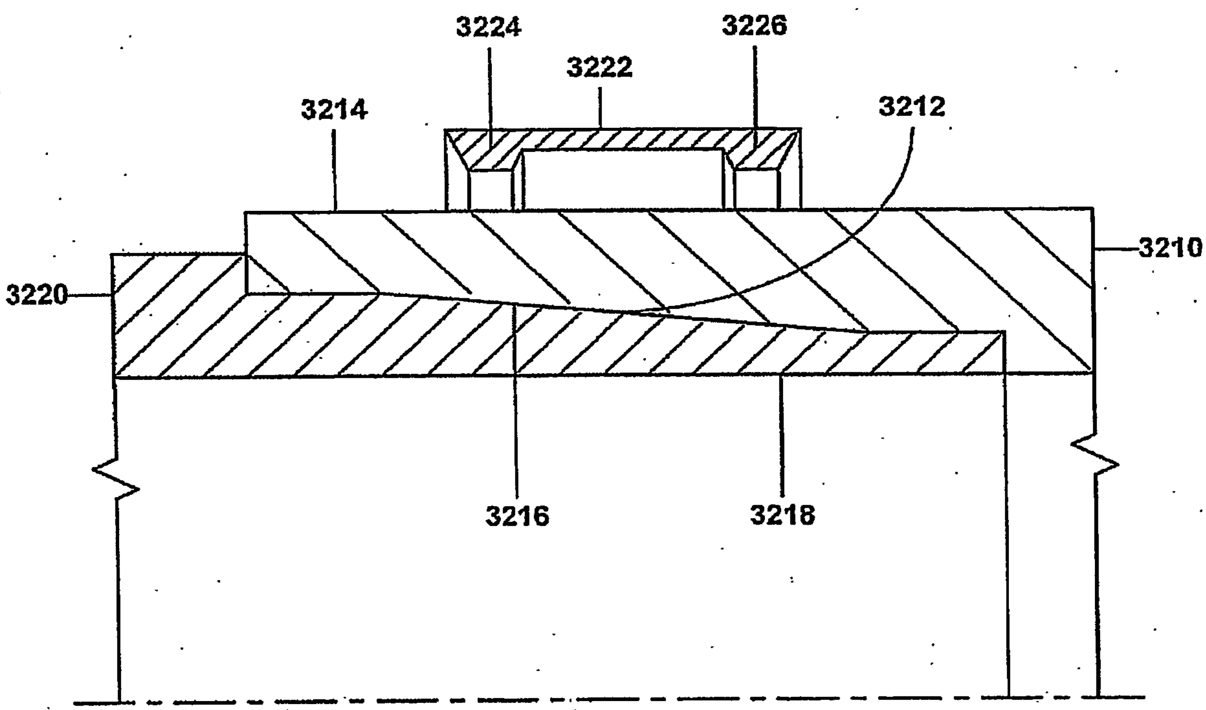


FIG. 32a

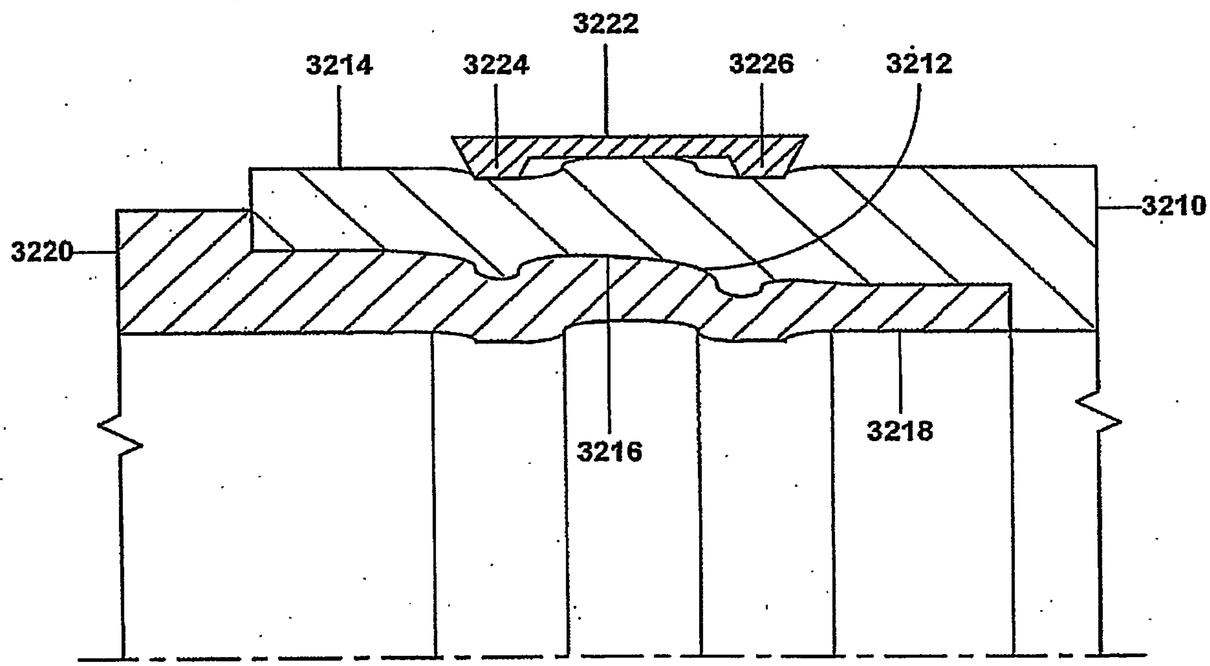


FIG. 32b

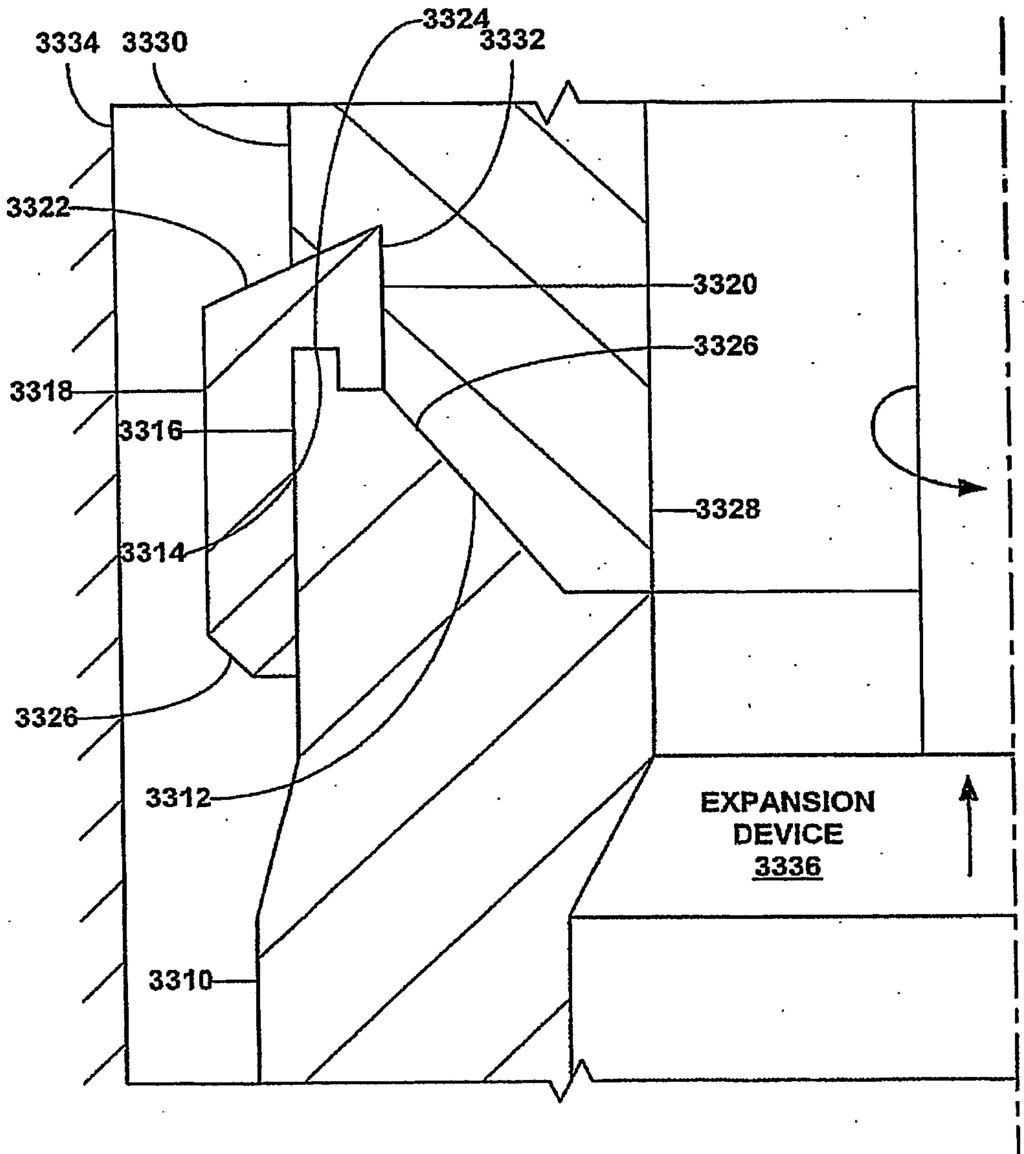
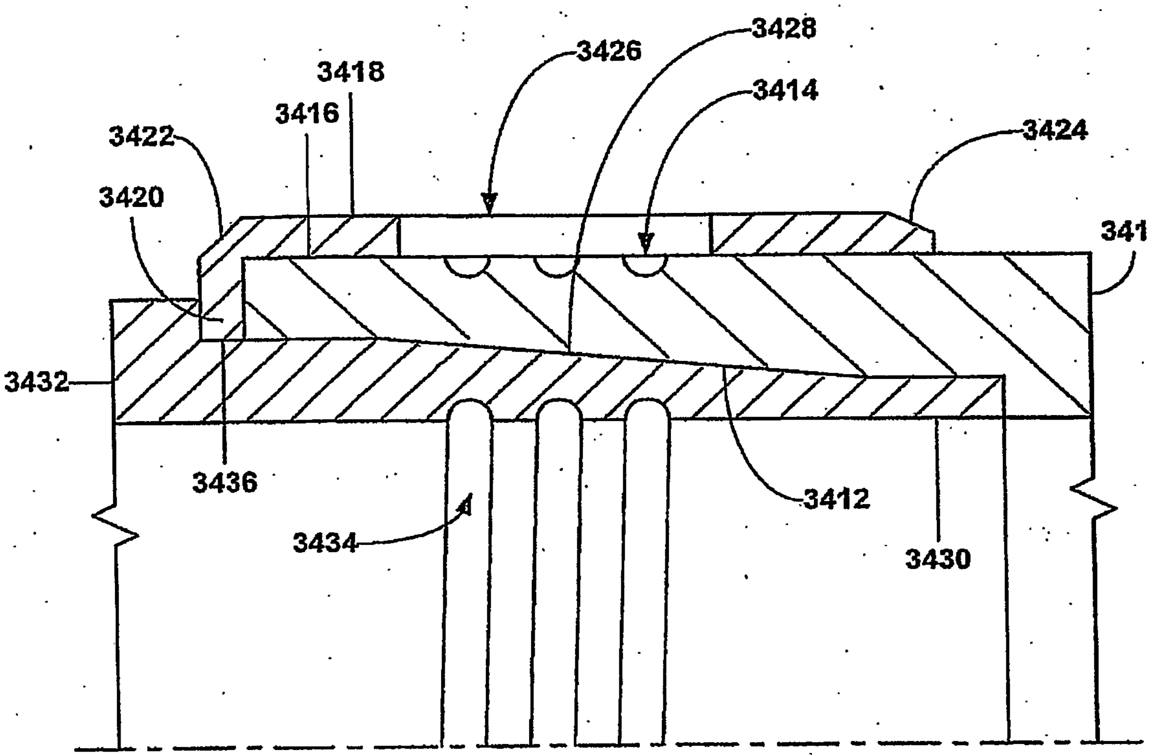

3334
3330
3324
3332
3322
3320
3326
3318
3316
3328
3314
3326
3312
EXPANSION
DEVICE
3336
3310

FIG. 33


3428
3426
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3414
3416
3422
3424
3420
3410
3432
3436
3412
3434
3430

FIG. 34a

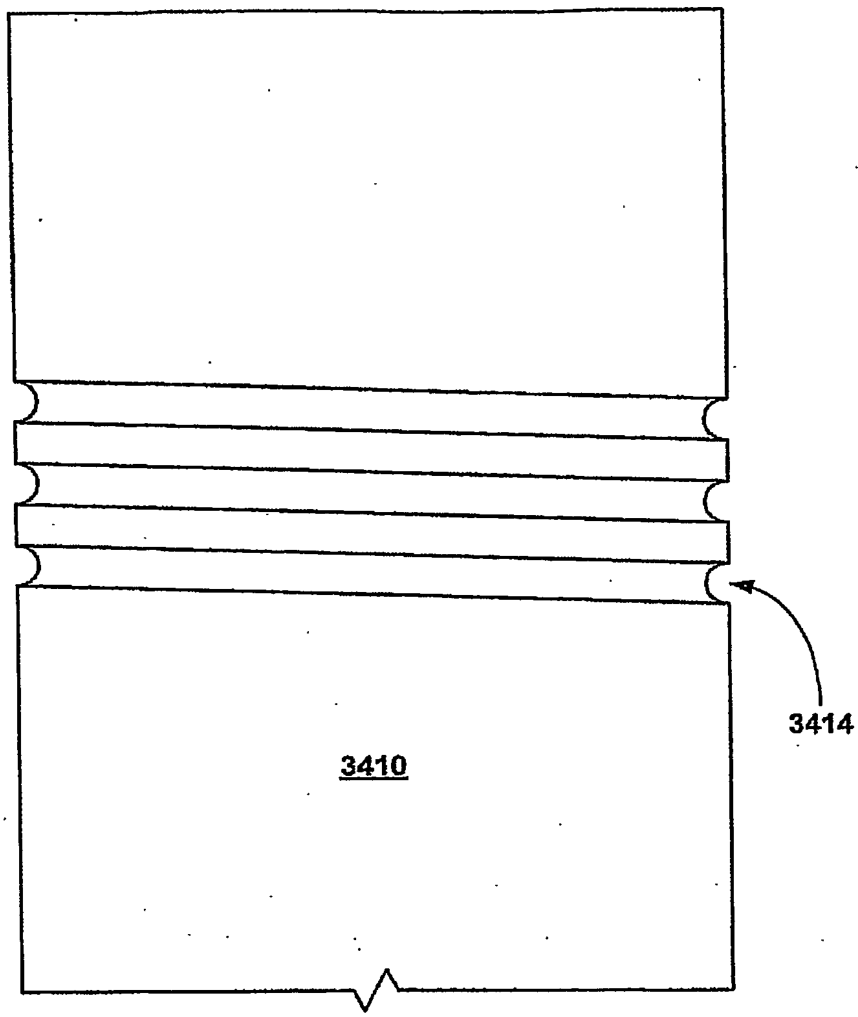


Fig. 34b

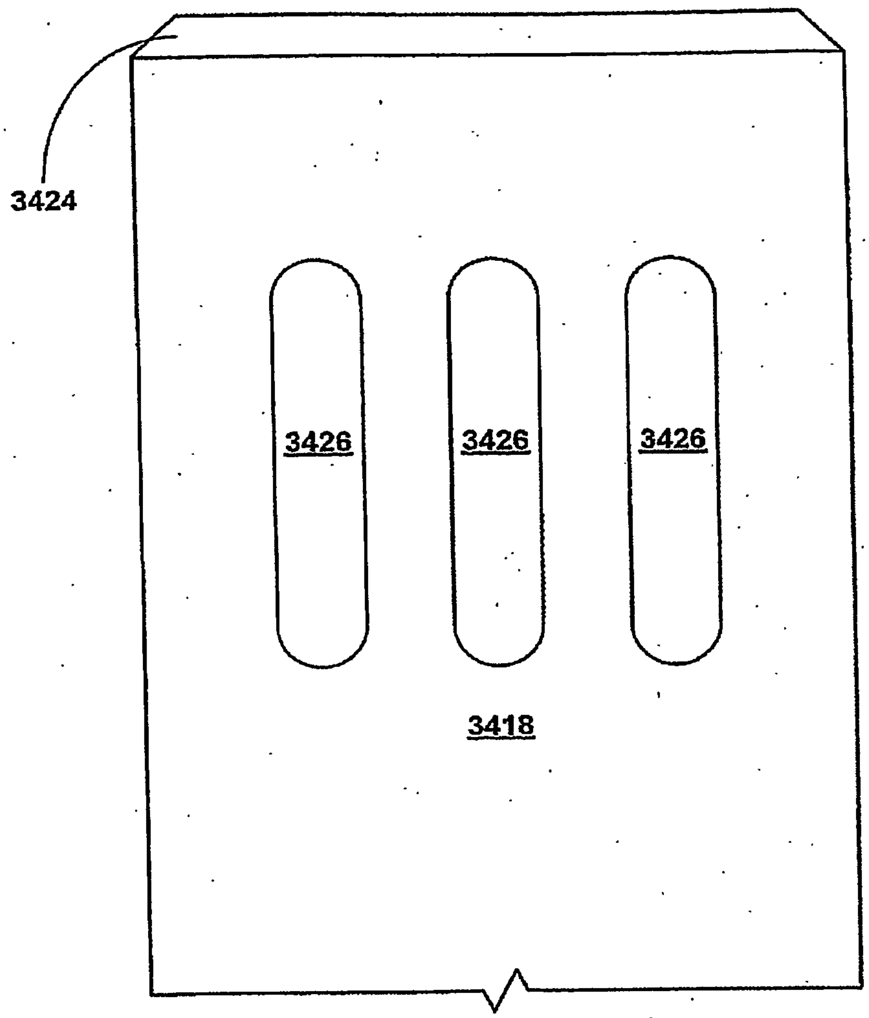


Fig. 34c

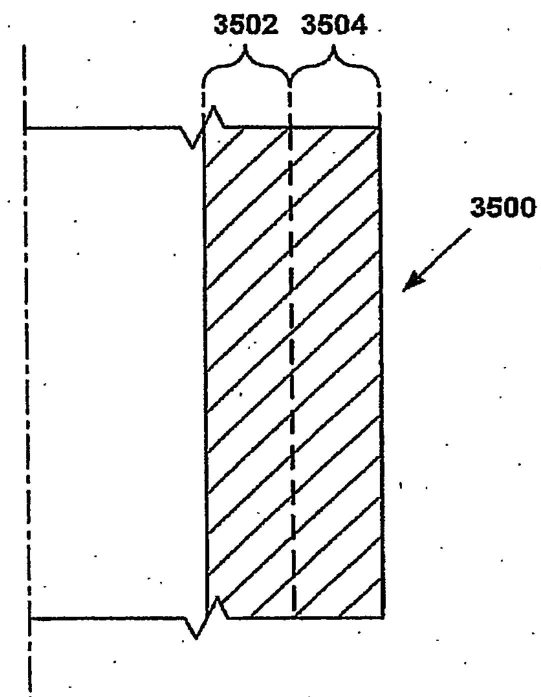


FIG. 35a

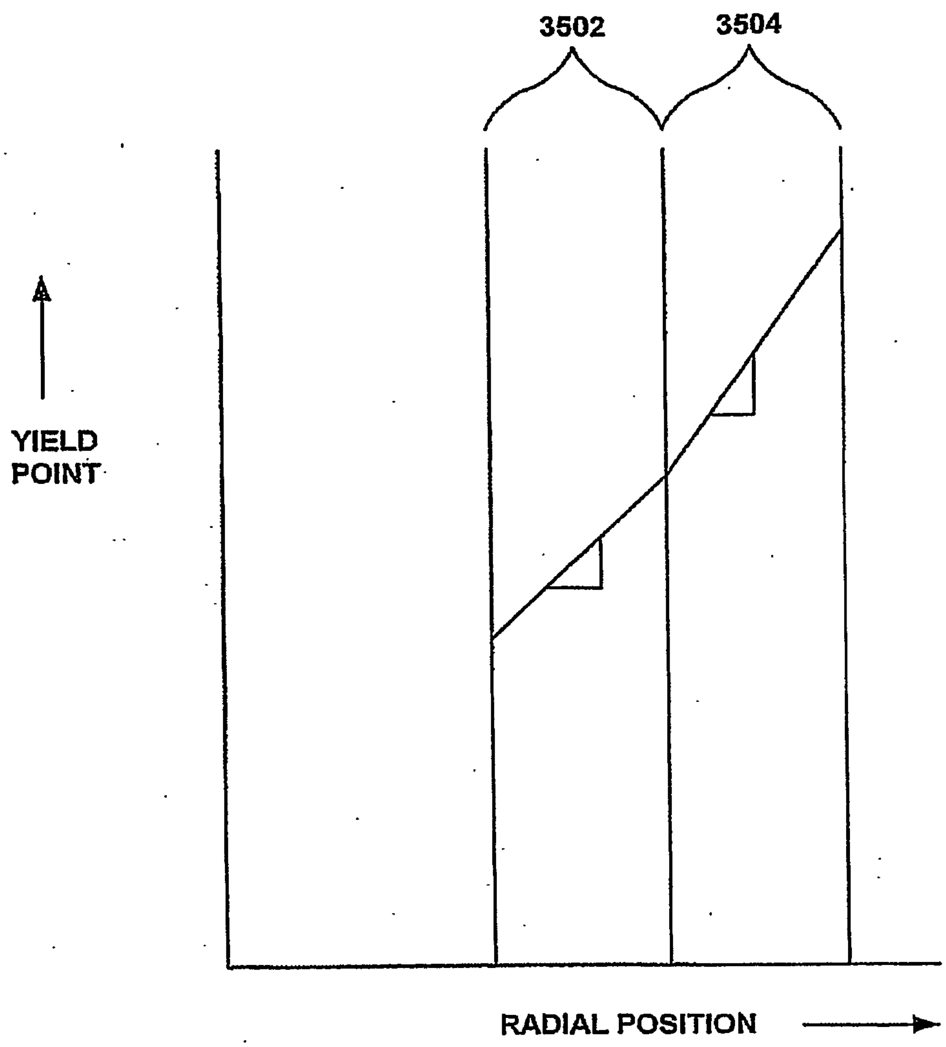


FIG. 35b

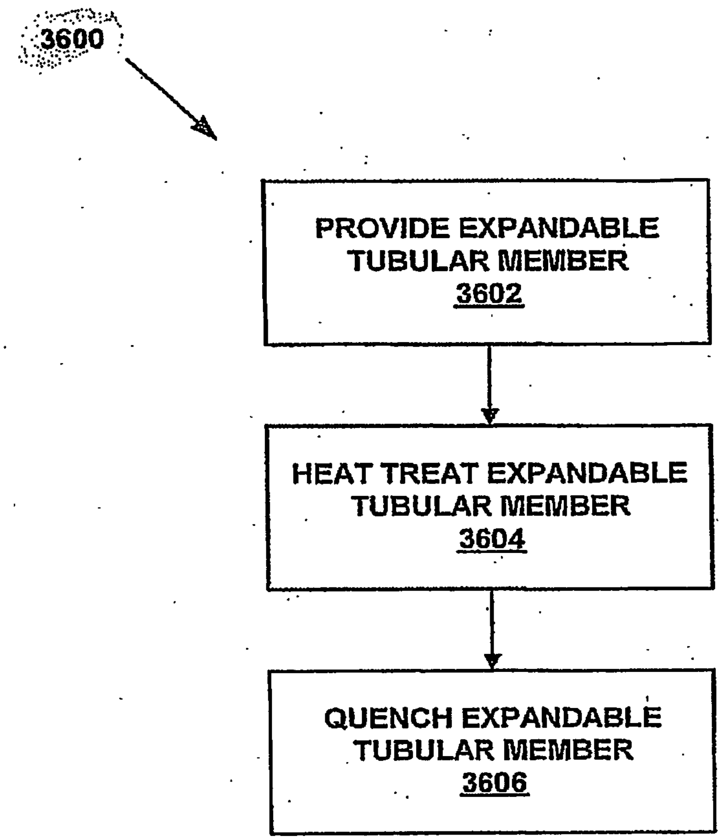

3600
PROVIDE EXPANDABLE TUBULAR MEMBER
3602
HEAT TREAT EXPANDABLE TUBULAR MEMBER
3604
QUENCH EXPANDABLE TUBULAR MEMBER
3606

FIG. 36a

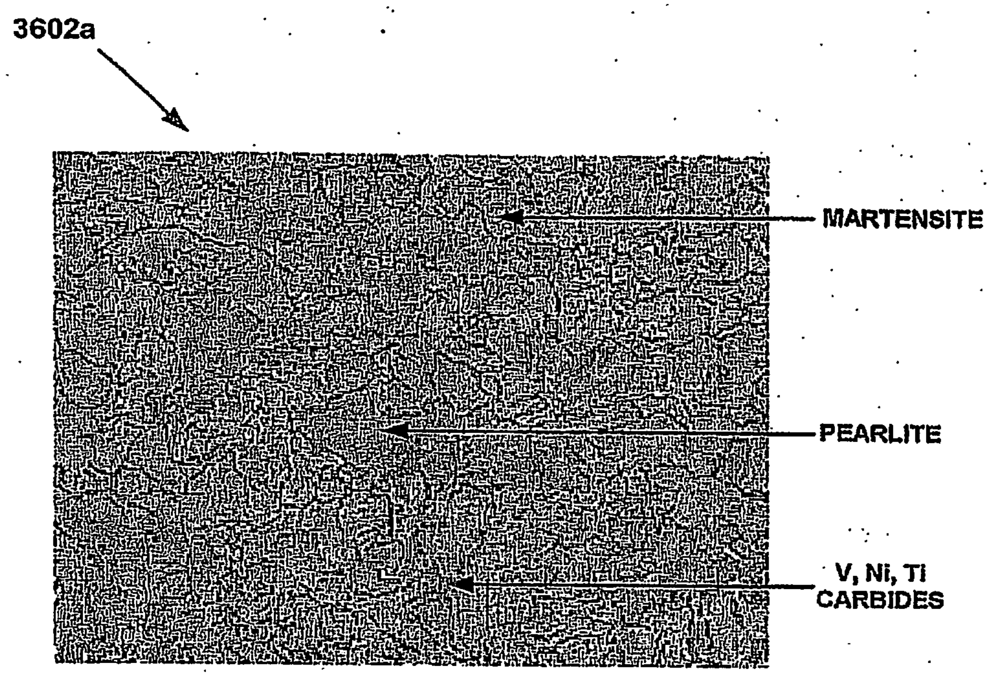


Fig. 36b

3602a

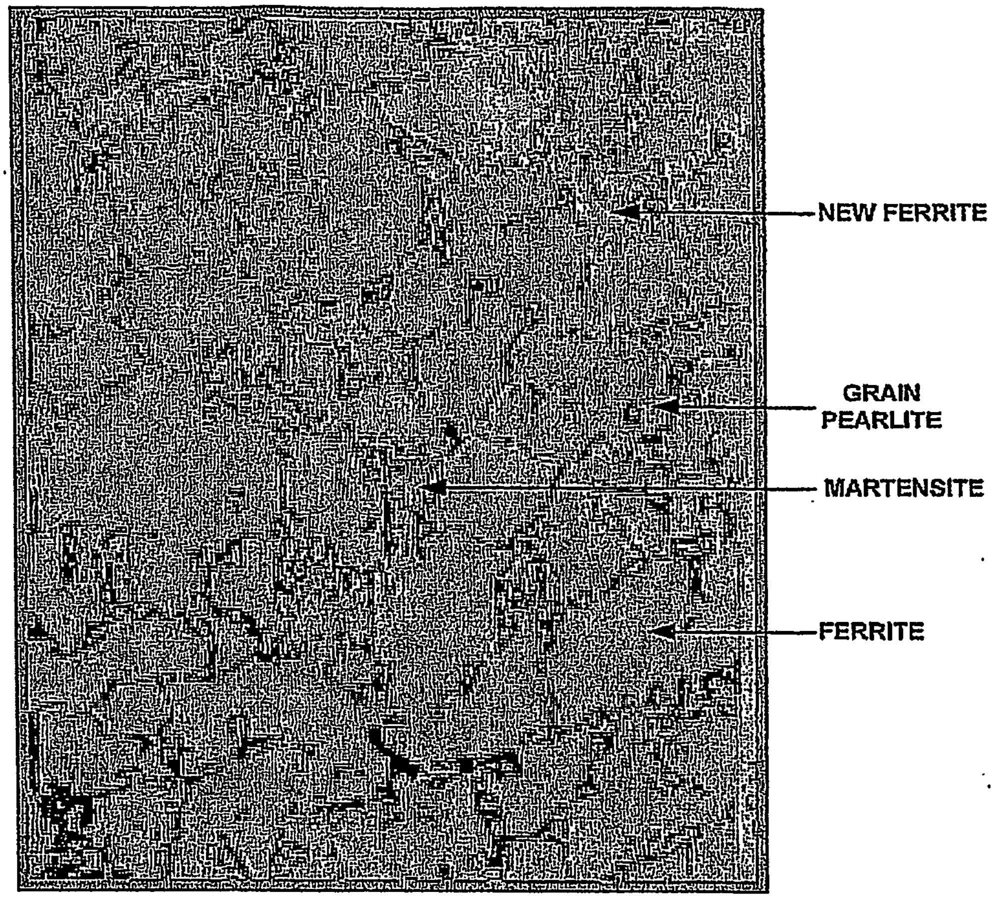


Fig. 36c

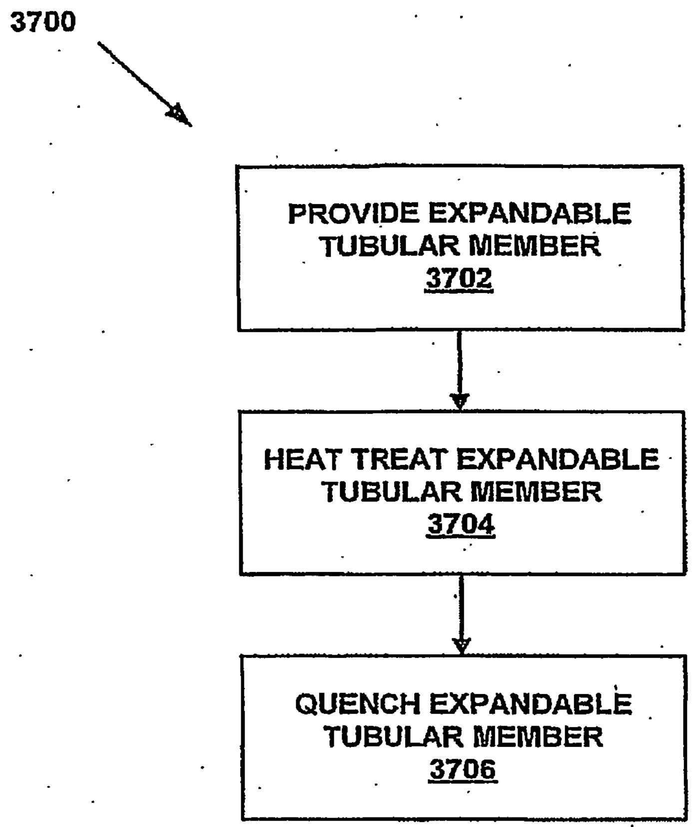

3700
PROVIDE EXPANDABLE TUBULAR MEMBER
3702
HEAT TREAT EXPANDABLE TUBULAR MEMBER
3704
QUENCH EXPANDABLE TUBULAR MEMBER
3706

FIG. 37a

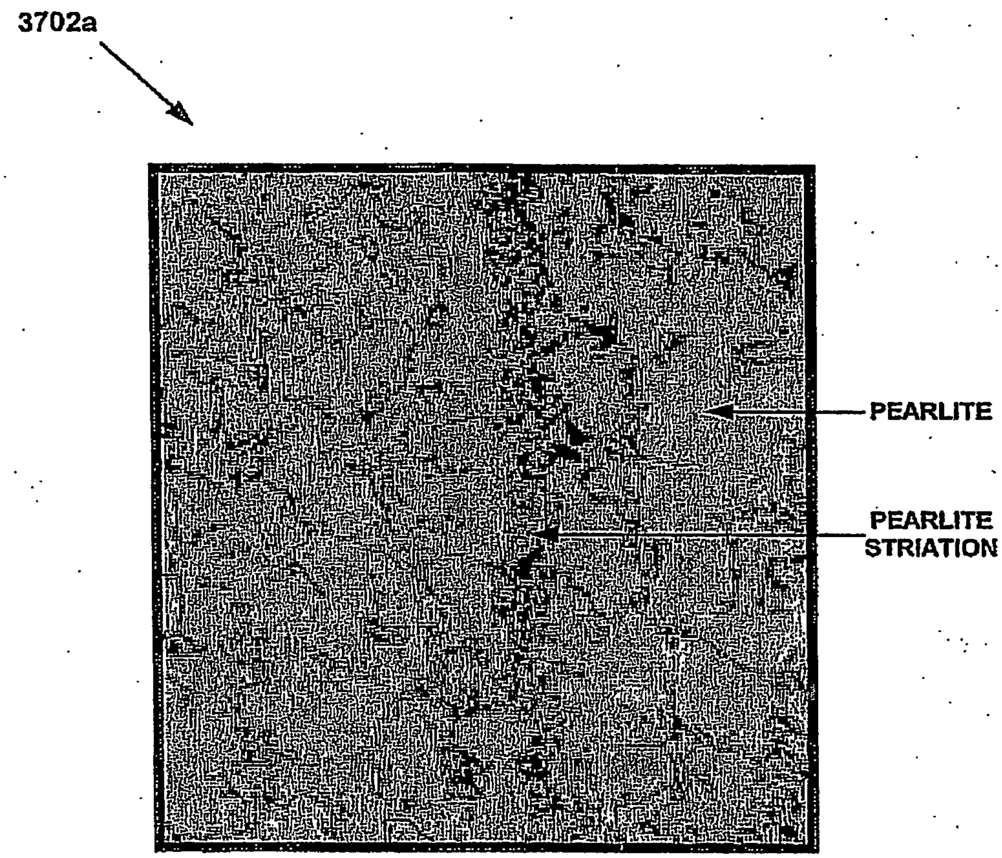


Fig. 37b

3702a

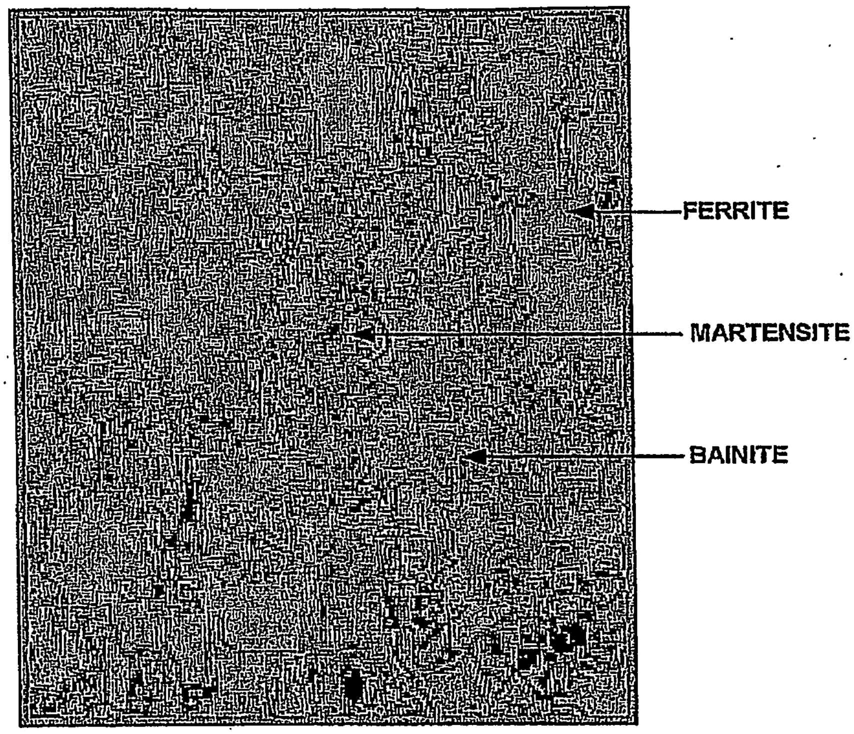


Fig. 37c

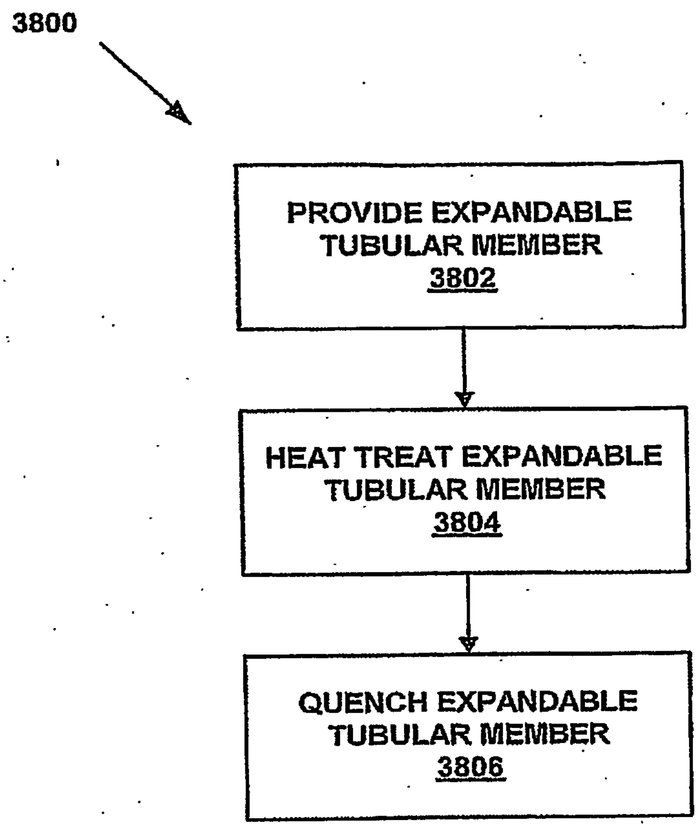

3800
PROVIDE EXPANDABLE TUBULAR MEMBER 3802
HEAT TREAT EXPANDABLE TUBULAR MEMBER 3804
QUENCH EXPANDABLE TUBULAR MEMBER 3806

FIG. 38a

3802a

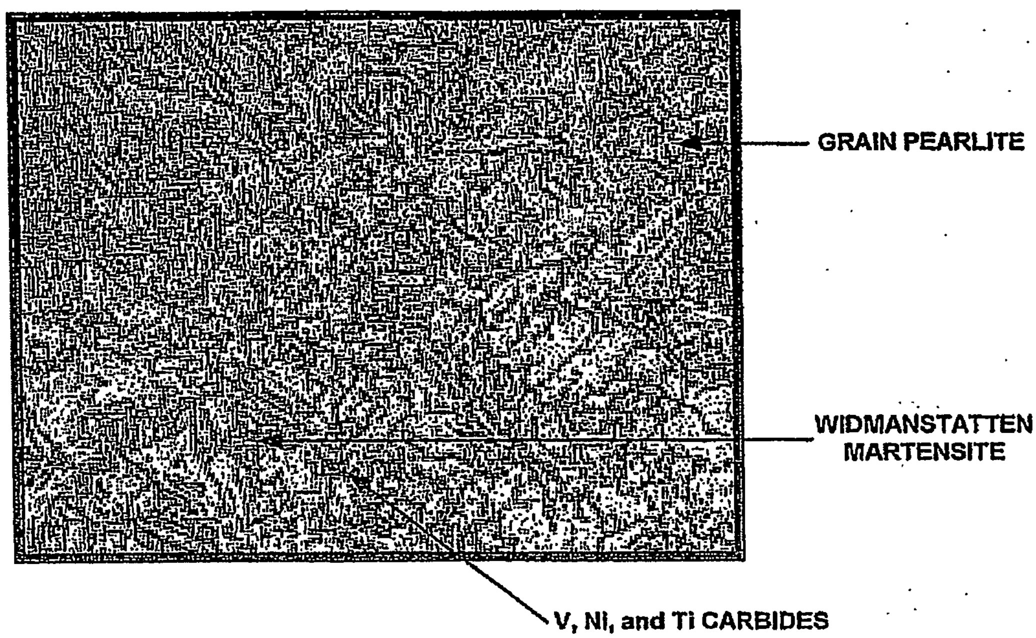


Fig. 38b

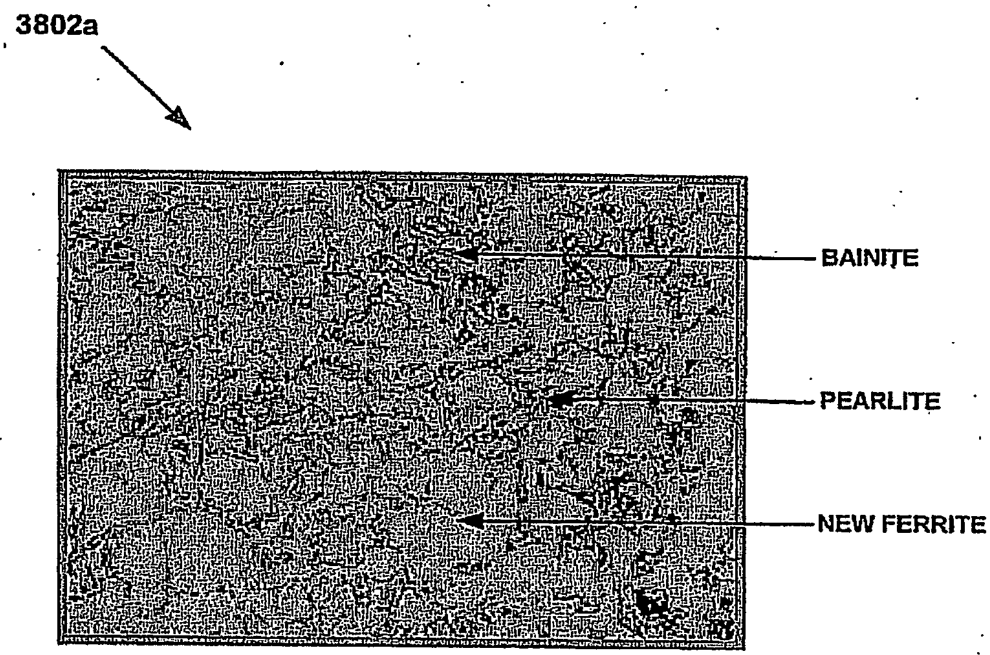


Fig. 38c

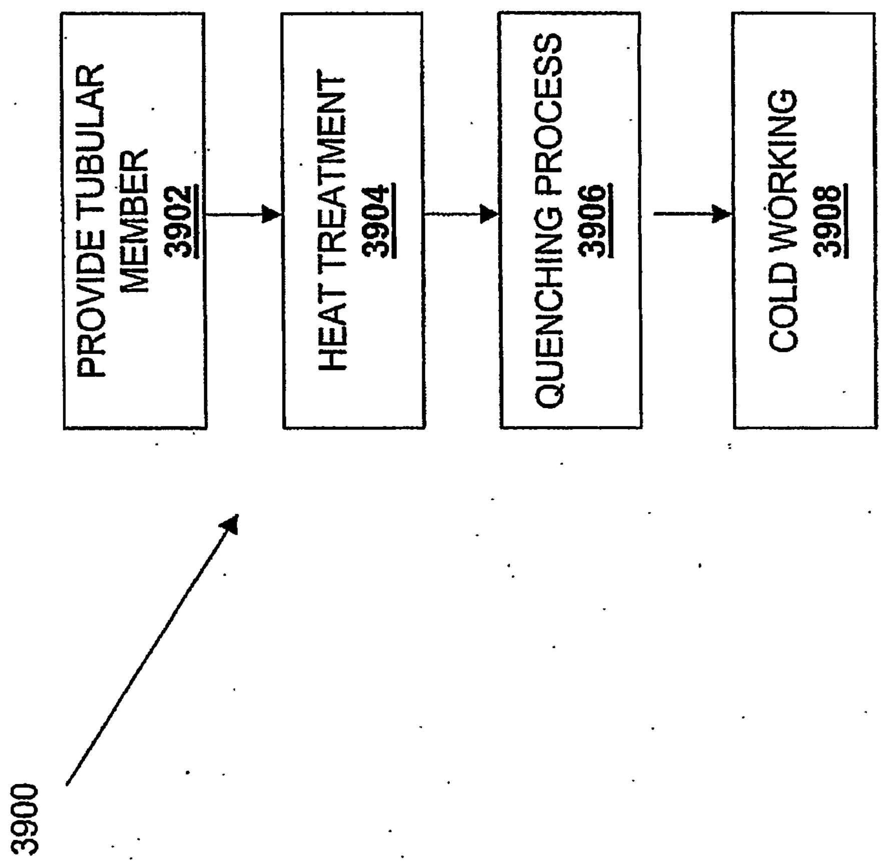

3900
PROVIDE TUBULAR MEMBER
3902
HEAT TREATMENT
3904
QUENCHING PROCESS
3906
COLD WORKING
3908

FIGURE 39

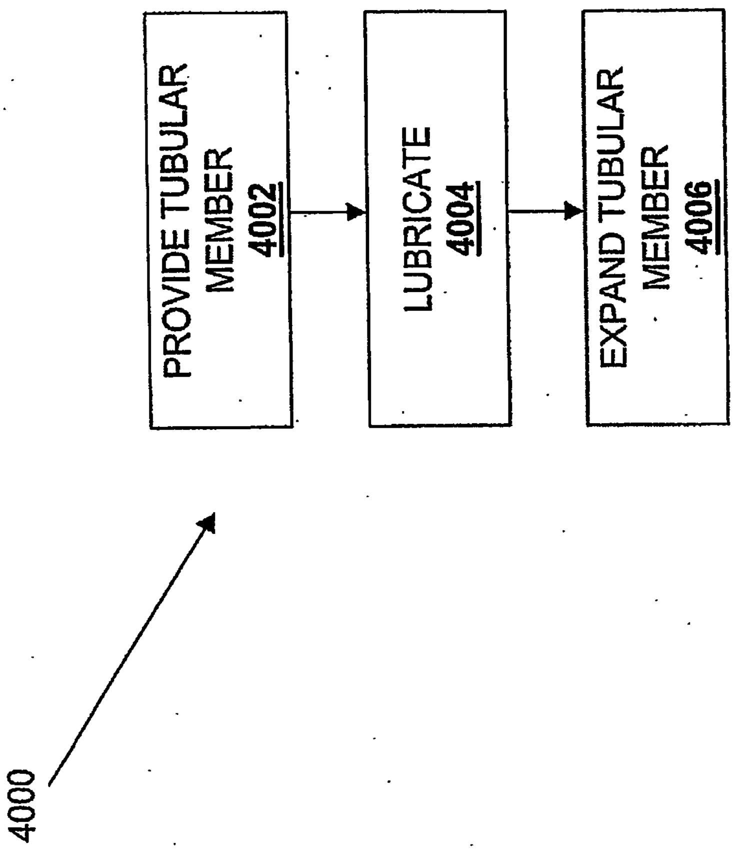

PROVIDE TUBULAR MEMBER
4002
LUBRICATE
4004
EXPAND TUBULAR MEMBER
4006
4000

FIGURE 40

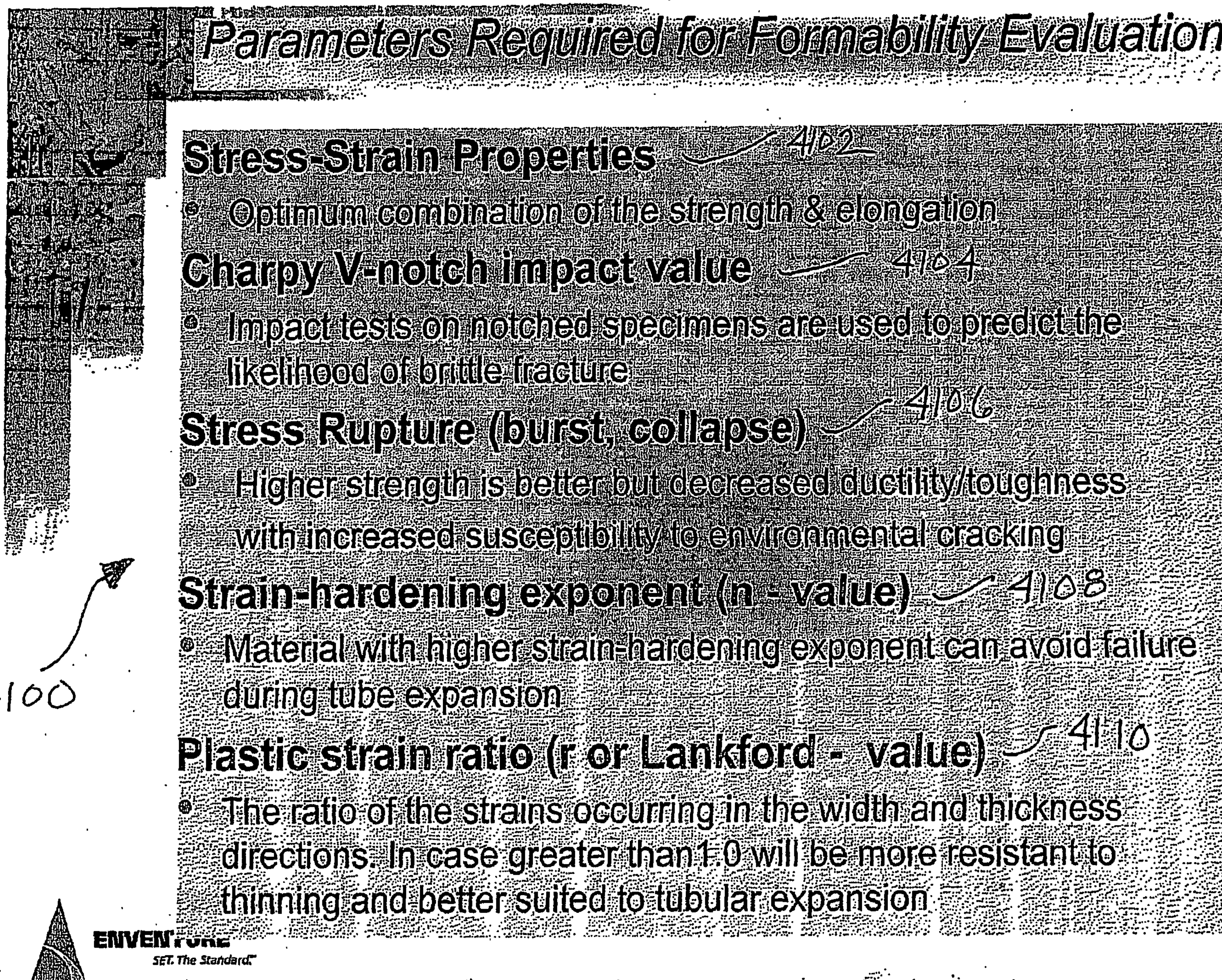

Parameters Required for Formability Evaluation
Stress-Strain Properties 4102
Optimum combination of the strength & elongation
Charpy V-notch impact value 4104
Impact tests on notched specimens are used to predict the likelihood of brittle fracture
Stress Rupture (burst, collapse) 4106
Higher strength is better but decreased ductility/toughness with increased susceptibility to environmental cracking
Strain-hardening exponent (n - value) 4108
Material with higher strain-hardening exponent can avoid failure during tube expansion
Plastic strain ratio (r or Lankford - value) 4110
The ratio of the strains occurring in the width and thickness directions. In case greater than1.0 will be more resistant to thinning and better suited to tubular expansion
4100
ENVENTURE
SET. The Standard.

FIGURE 41

4200

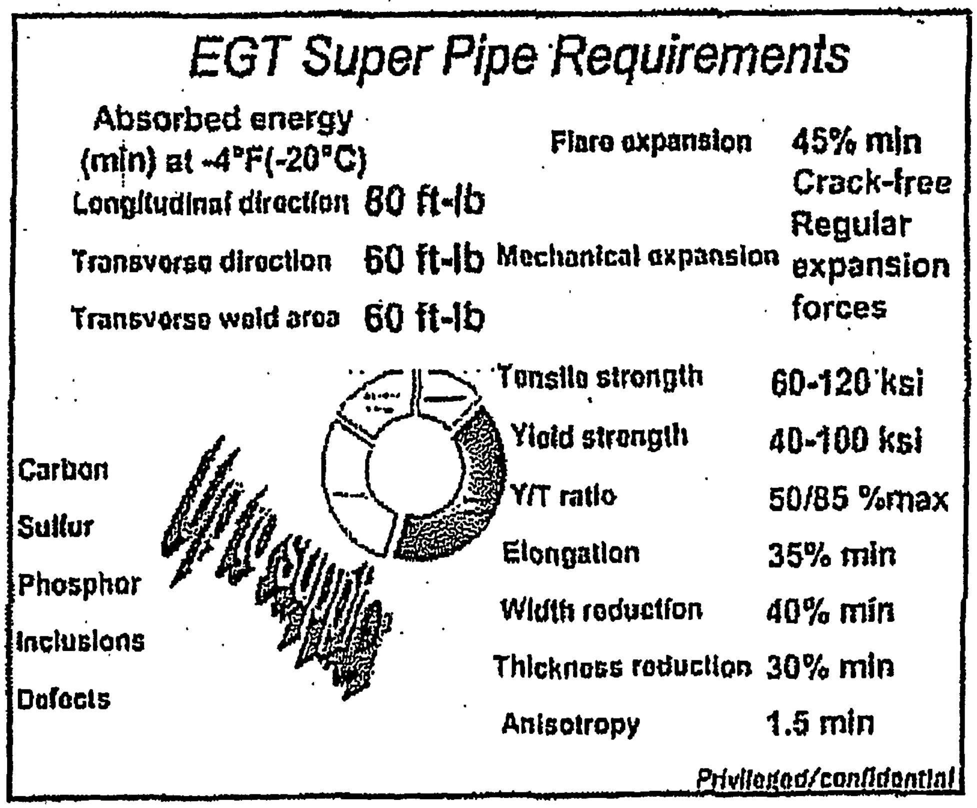


FIGURE 42

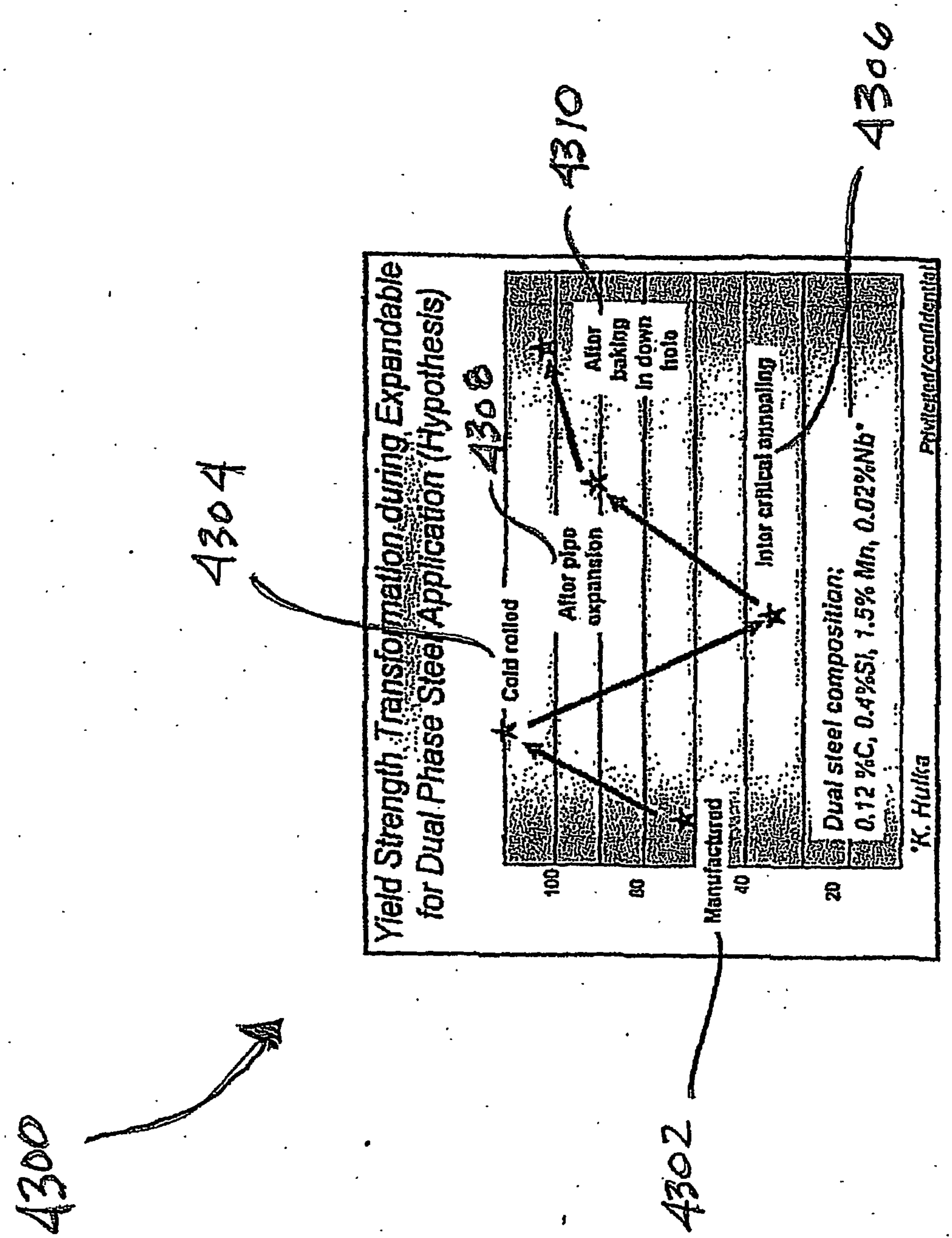

4300
Yield Strength Transformation during Expandable for Dual Phase Steel Application (Hypothesis)
4304
4308
4310
4306
Cold rolled
After pipe expansion
After baking In down hole
Inter critical annealing
Manufactured
100
80
40
20
Dual steel composition: 0.12 %C, 0.4%Si, 1.5% Mn, 0.02%Nb*
*K. Hulka
Privileged/confidential
4302

FIGURE 43

EGT Pipe Requirements

Absorbed energy (min) at -4°F(-20°C)	
Longitudinal direction	80 ft-lb
Transverse direction	60 ft-lb
Transverse weld area	60 ft-lb

Flare expansion	45% min
Mechanical expansion	Crack-free, Regular expansion forces

Tensile strength	80-100 ksi
Yield strength	60-90 ksi
Y/T ratio	85 %max
Elongation	22% min
Width reduction	30% min
Thickness reduction	35% min
Anisotropy	0.8 min

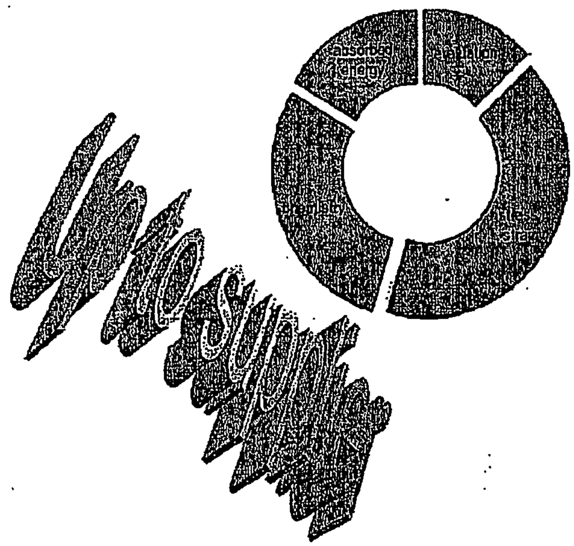
Carbon

Sulfur

Phosphor

Inclusions

Defects



ENVENTURE
SET. The Standard.

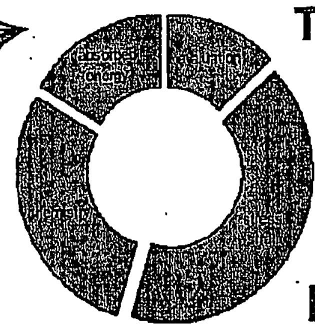
4400

FIGURE 44

EGT Super Pipe Requirements

Absorbed energy (min) at -4°F(-20°C)		Flare expansion	75% min Crack-free
Longitudinal direction	80 ft-lb		
Transverse direction	60 ft-lb	Mechanical expansion	Regular expansion forces
Transverse weld area	60 ft-lb		

4500



Tensile strength	60-120 ksi
Yield strength	40-100 ksi
Y/T ratio	50/85 %max
Elongation	35% min
Width reduction	40% min
Thickness reduction	30% min
Anisotropy	1.5 min

Carbon

Sulfur

Phosphor

Inclusions

Defects

ENVENTURE
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FIGURE 45

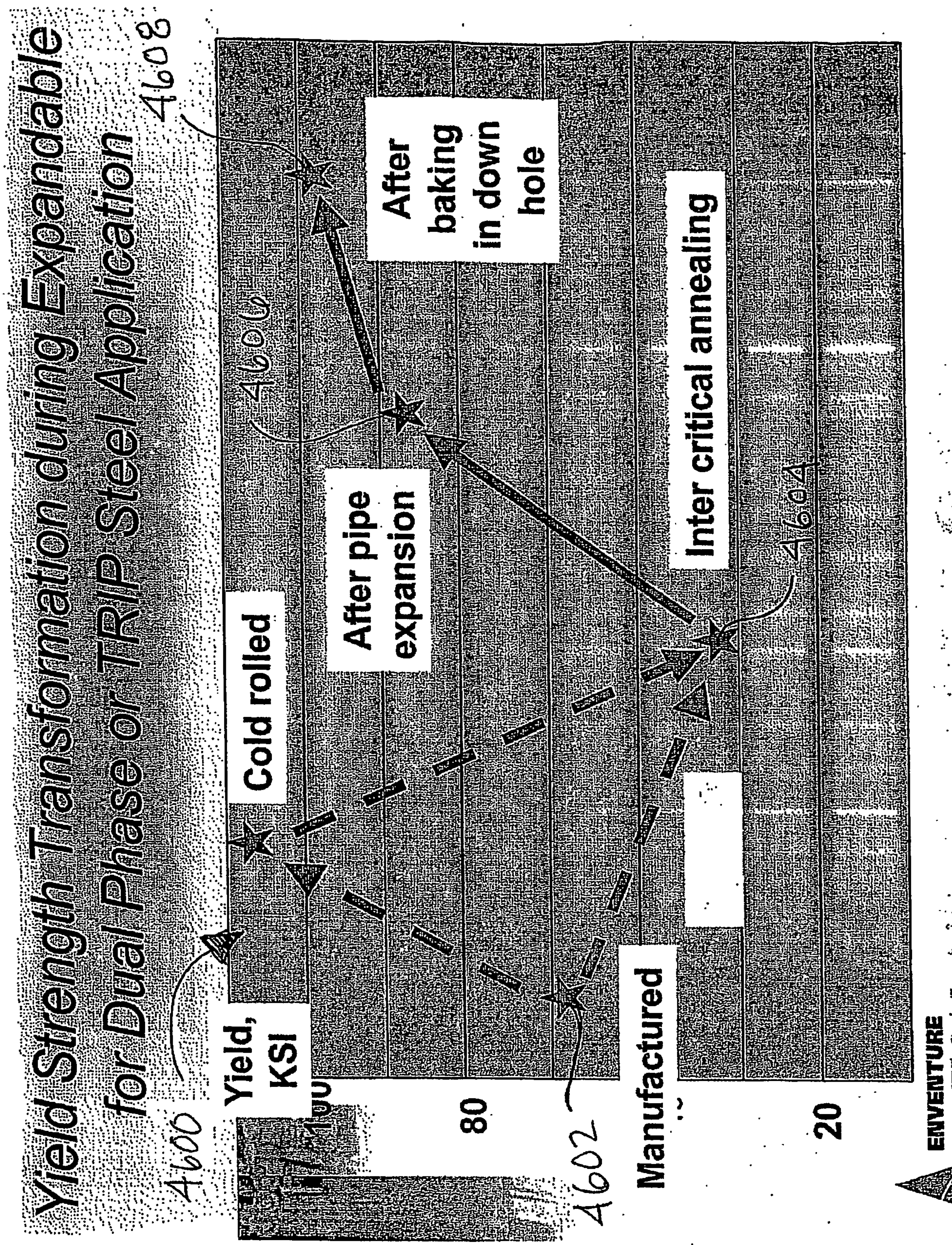
Yield Strength Transformation during Expandable
for Dual Phase or TRIP Steel Application
4608
After baking in down hole
4606
After pipe expansion
Cold rolled
Inter critical annealing
4604
4600
Yield, KSI
80
20
Manufactured
4602
ENVENTURE
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FIGURE 4G

"History" Pipe Performance*

(High speed tube welding and optimum reducing technology)

- New metallurgy
- Warm-reducing new manufacturing process
- High strength & excellent formability
- 20 % higher elongation
- High r-value (=strain in different directions)

4700

	Yield, ksi	Tensile ksi	Elongation %
"History" pipe	76.8	82.8	32
ERW pipe	64.8	85.0	18

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FIGURE 47

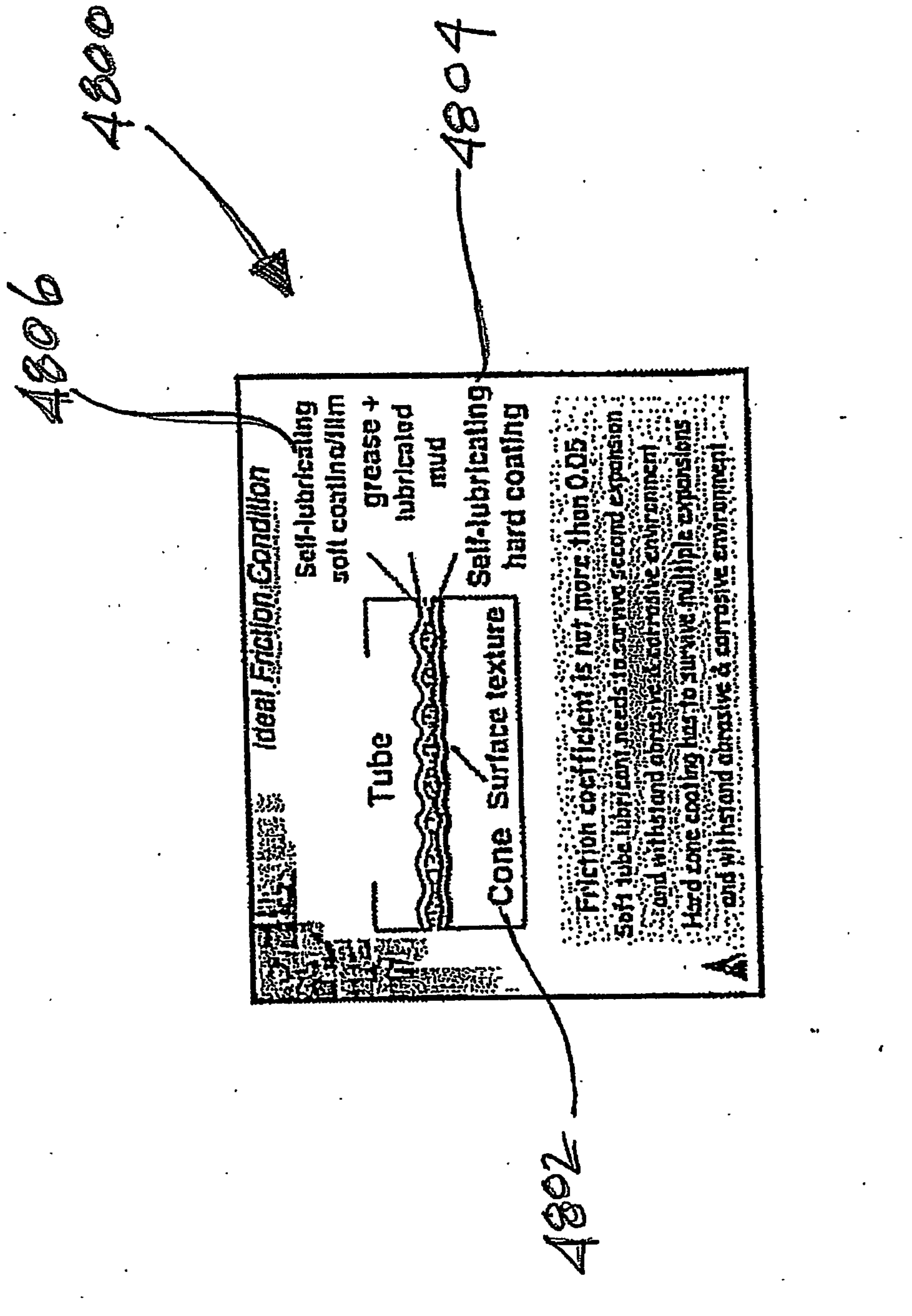

4800
4806
4804
4802
Ideal Friction Condition
Self-lubricating soft coating/film
grease + lubricated mud
Self-lubricating hard coating
Tube
Surface texture
Cone
Friction coefficient is not more than 0.05
Soft tube lubricant needs to survive second expansion and withstand abrasive & corrosive environment
Hard cone coating has to survive multiple expansions and withstand abrasive & corrosive environment

FIGURE 48

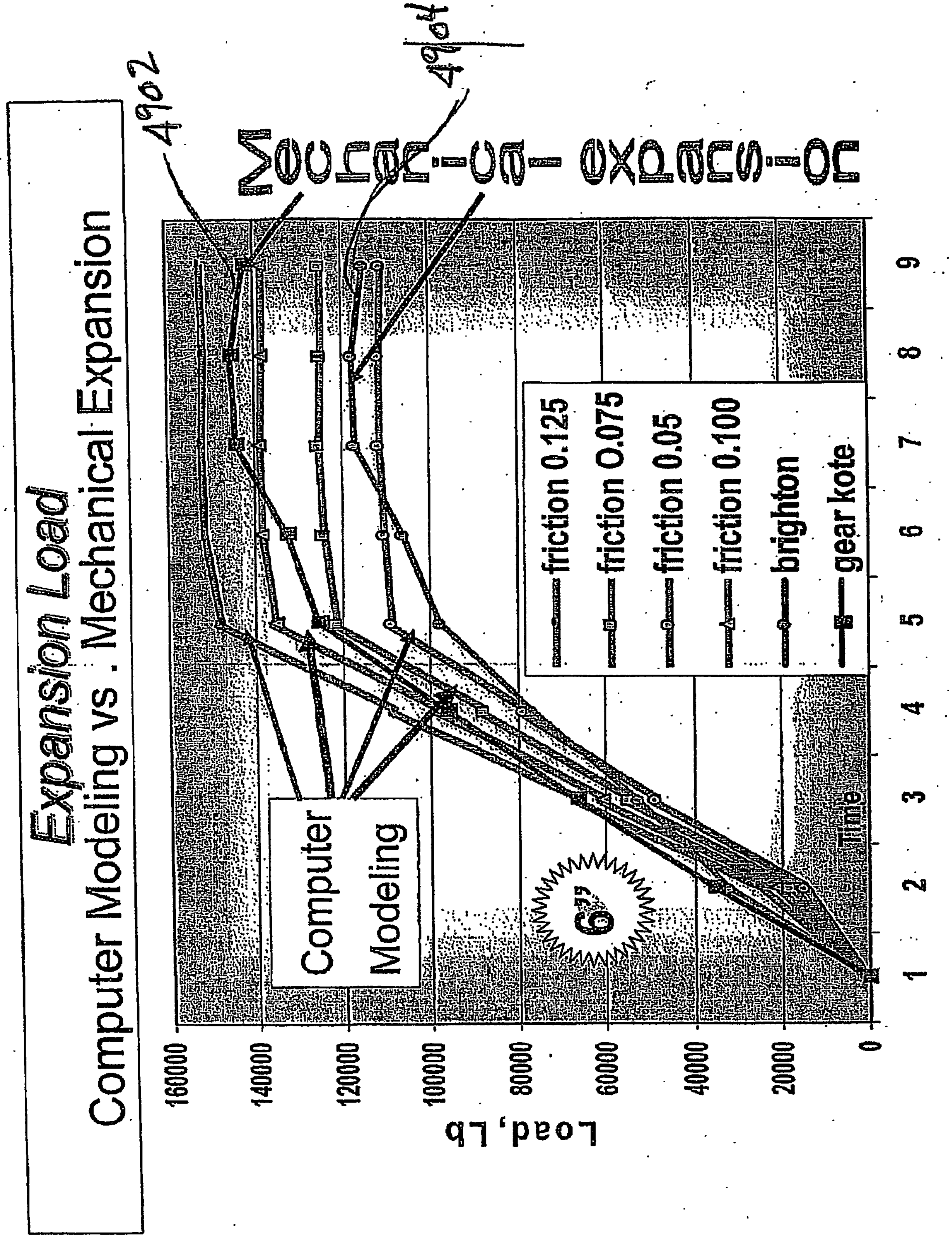
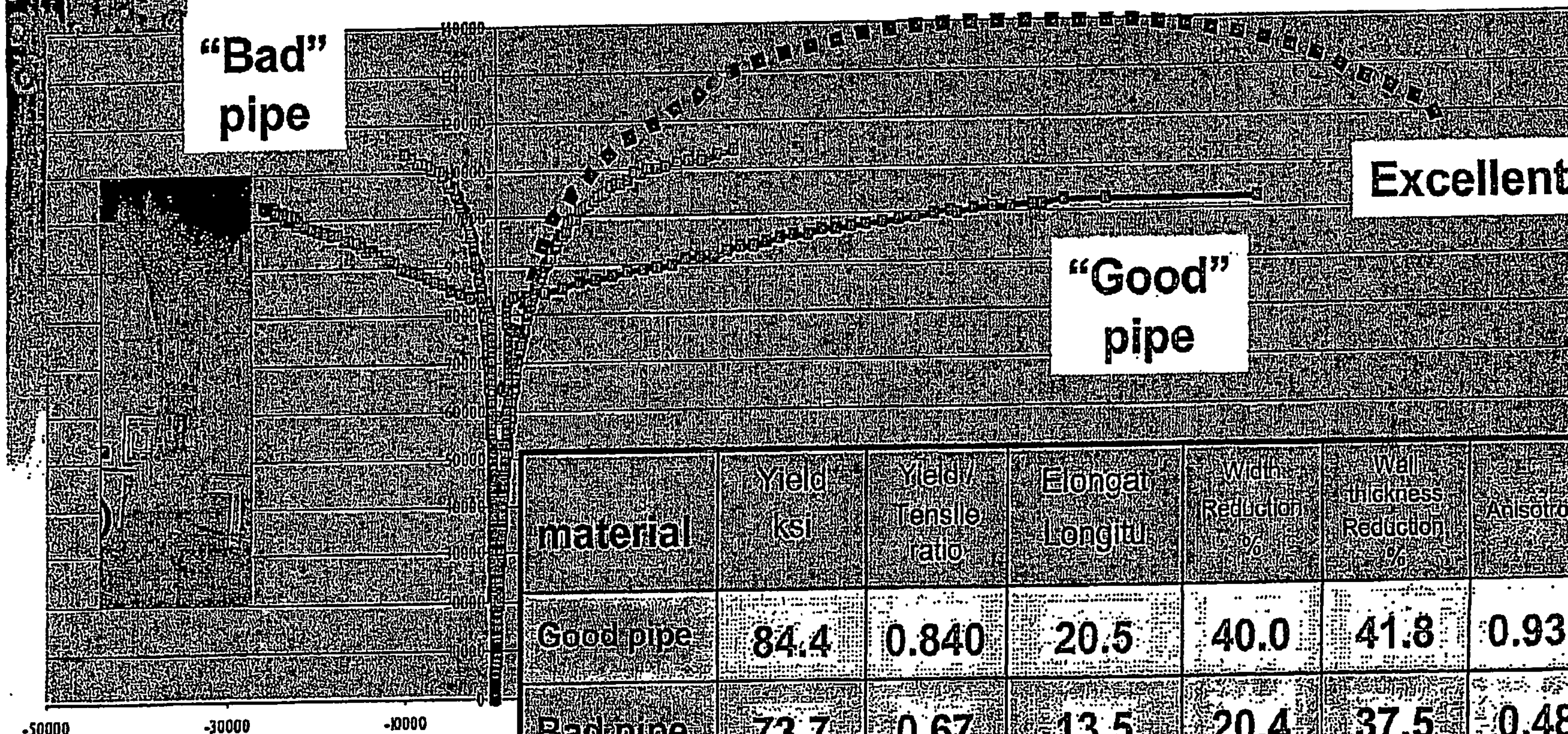

Expansion Load
Computer Modeling vs . Mechanical Expansion
Mechanical Expansion
4902
4904
Computer Modeling
6"
Load, Lb
160000
140000
120000
100000
80000
60000
40000
20000
0
Time
1
2
3
4
5
6
7
8
9
friction 0.125
friction 0.075
friction 0.05
friction 0.100
brighton
gear kote

FIGURE 49

Engineering Stress vs. Strain Curve

Hypothetical prediction



material	Yield ksi	Yield/ Tensile ratio	Elongat Longitu	Width Reduction %	Wall thickness Reduction %	Anisotropy
Good pipe	84.4	0.840	20.5	40.0	41.8	0.935
Bad pipe	73.7	0.67	13.5	20.4	37.5	0.48
Excellent	40/80	<0.5	>30	>45	>30	>1.5

5000

ENVENTURE
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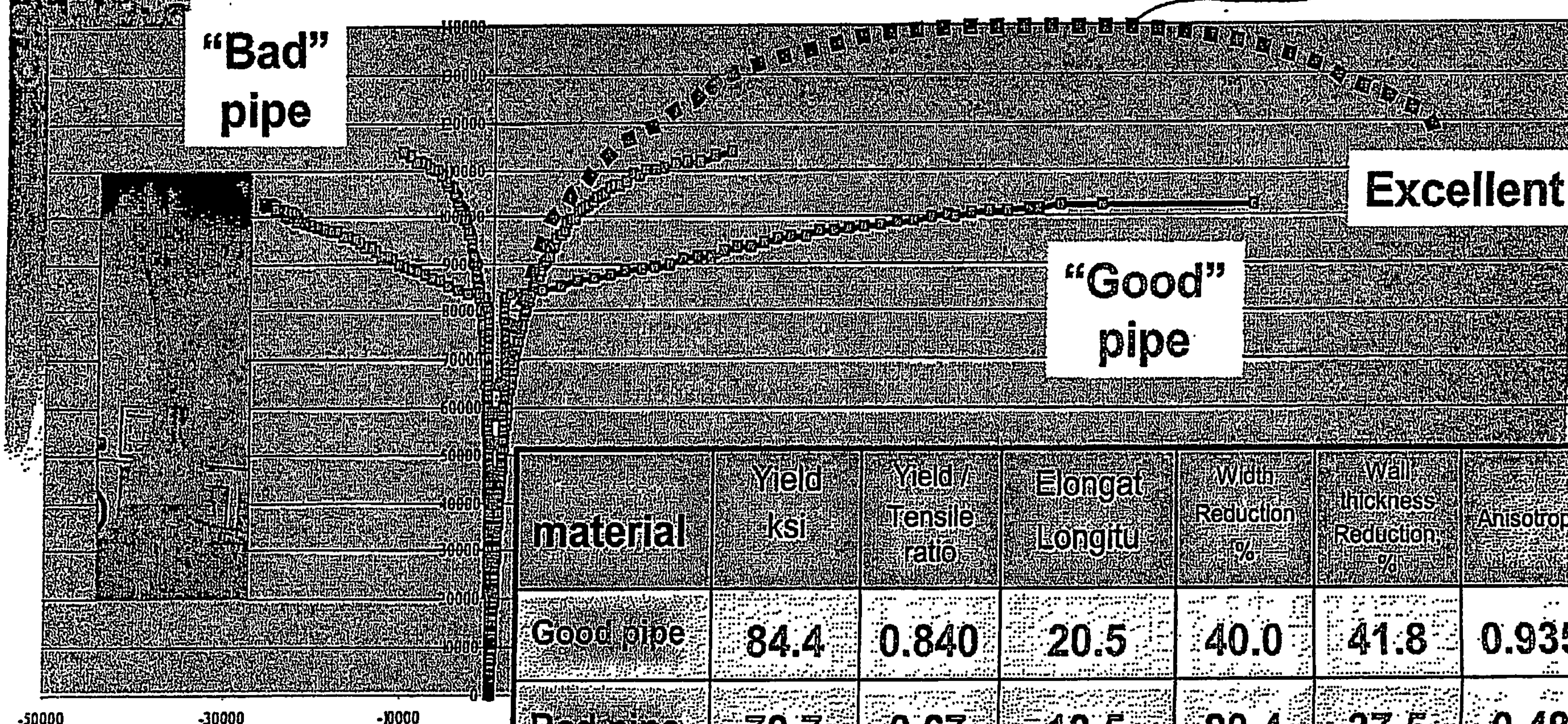
FIGURE 50a

Engineering Stress vs. Strain Curve

Hypothetical prediction



material	Yield ksi	Yield / Tensile ratio	Elongat Longitu	Width Reduction %	Wall thickness Reduction %	Anisotropy
Good pipe	84.4	0.840	20.5	40.0	41.8	0.935
Bad pipe	73.7	0.67	13.5	20.4	37.5	0.48
Excellent	40/80	<0.5	>30	>45	>30	>1.5

ENVENTURE
SET. The Standard.

FIGURE 50b

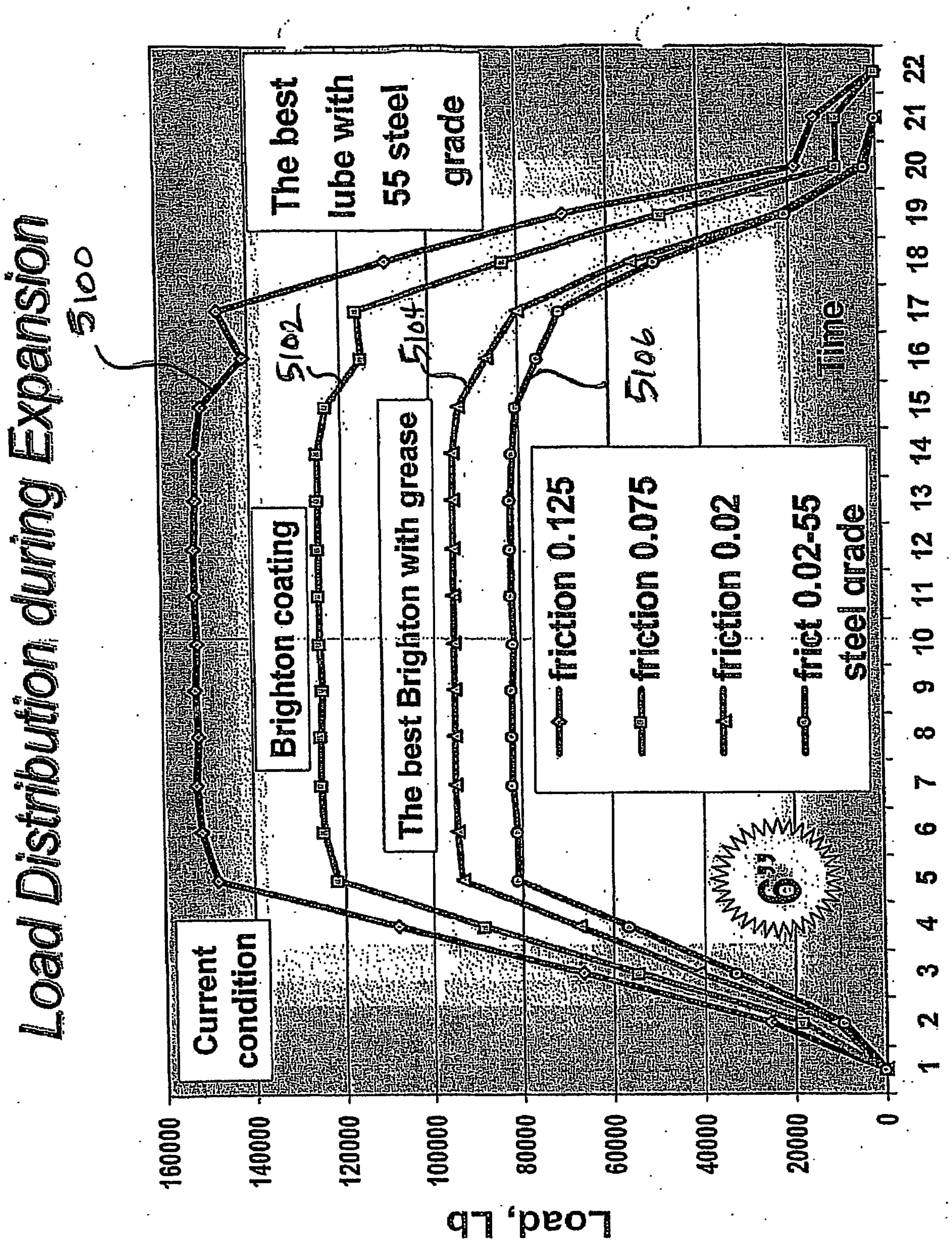

Load Distribution during Expansion
5100
5102
5104
5106
Current condition
Brighton coating
The best Brighton with grease
The best lube with 55 steel grade
friction 0.125
friction 0.075
friction 0.02
frict 0.02-55 steel grade
Load, Lb
160000
140000
120000
100000
80000
60000
40000
20000
0
Time
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

FIGURE 51

Collapse Improvement Estimation

6”

		Friction	Expansion force	Wall thickness	D/t after	Collapse Ksi
5200	Current 6” x .305 BSFL lube	0.125	145,900	0.305	24.8	2,379
5202	Brighton lube Application	0.075	143,000	0.350	21.6	3,243
5204	Best Brighton With grease	0.02	149,900	0.450	16.8	5,837
5206	Best lube with 55 ksi steel	0.02	125,800	0.500	15.1	5,359
5208	Best lube and steel with 55 Ksi yield before and 100 Ksi after pipe expansion	0.02	126,800	0.500	15.1	8,443

FIGURE 52

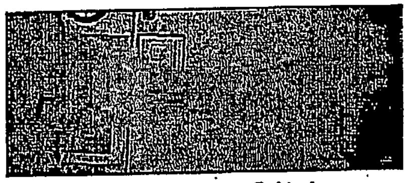
Pipe Compositions

Sample	C	Mn	P	S	Si	Cu	Ni	Cr	V	Mo	Nb	Ti
5302												
5304 JFE–A*	.065	1.44	.01	.002	.24	.01	.01	.02	.04	.01	.03	.01
5306 JFE–B*	.18	1.28	.017	.004	0.29	.01	.01	.03	.03	.03	.01	.01
5308 X52x0.37	.08	.82	.006	.003	.30	.16	.05	.05	.06	.01	.03	.01
X52x0.52	.03	1.48	.014	.002	.16	.02	.01	0.02	06	.01	.03	.01

FIGURE 53

5400

Tensile Characteristics before and after Mechanical Expansion



NT 55HE Pipe, 16 %

	Yield ksi (5402)	Yield ratio (5404)	Elongation % (5406)	Width reduction % (5408)	Wall thickness reduction, % (5410)	Anisotropy % (5412)
Before	61.5	.62	17	26	47	.46
After	74.7	.77	14	28	54	.44
Change %	21.4	24	- 18	7.7	14.5	- 4.4

FIGURE 54

5500

Tensile Characteristics before and after Mechanical Expansion

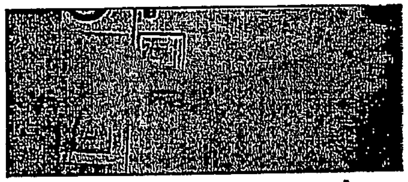
JFE "History" Pipe, 15.6 %

	5502 Yield ksi	5504 Yield ratio	5506 Elongation %	5508 Width reduction %	5510 Wall thickness reduction, %	5512 Anisotropy %
Before	61.9	.6	12	18	15	1.24
After	105	.75	4	13	14	.94
Change %	-70	-25	- 67	27.8	6.7	75

FIGURE 55

5600

Tensile Characteristics before and after Mechanical Expansion



VM 50, 24 %

	Yield ksi (5602)	Yield ratio (5604)	Elongation % (5606)	Width reduction % (5608)	Wall thickness reduction % (5610)	Anisotropy % (5612)
Before	64.9	.78	20	47	59	.72
After	71.5	.80	14	41	58	.60
Change %	10.2	2.6	- 30	- 13	- 1.7	- 16.7

FIGURE 56

5700

Tensile Characteristics before and after Mechanical Expansion

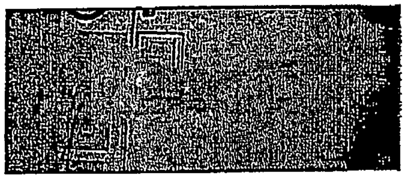
JFE option A

	Yield ksi 5702	Yield ratio 5704	Elongation% 5706	Width reduction 5708 %	Wall thickness reduction, % 5710	Anisotropy % 5712
Before	46.9	.69	53	-52	55	.93
16 % Expan.	65.9	.83	17	42	51	.78
24 % Expan	68.5	.83	5	44	54	.76
Change %	46	-20	91	15	2	18

FIGURE 57

Tensile Characteristics before and after Mechanical Expansion

5800



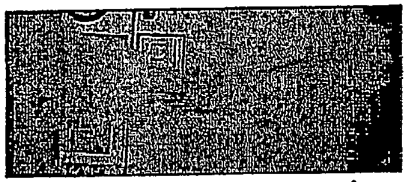
JFE, option A (#1) 16 %

	Yield ksi (5802)	Yield ratio (5804)	Elongation % (5806)	Width reduction % (5808)	Wall thickness reduction, % (5810)	Anisotropy % (5812)
Before	47.7	.69	23	46	53	0.81
After	65.9	.83	17	42	51	0.78
Change %	38	20	11	9	4	4

FIGURE 58

5900

Tensile Characteristics before and after Mechanical Expansion



JFE, option A (#1) 24 %

	5902 Yield ksi	5904 Yield ratio	5906 Elongation %	5908 Width reduction %	5910 Wall thickness reduction, %	5912 Anisotropy %
Before	47.7	.69	23	46	53	0.81
After	62.3	.71	12	40	52	.71
Change %	31	14	48	13	2	12

FIGURE 59

6000

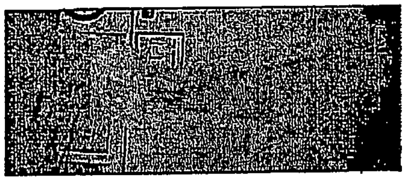
Tensile Characteristics before and after Mechanical Expansion
JFE option B

	Yield ksi 6002	Yield ratio 6004	Elongation% 6006	Width reduction 6008 %	Wall thickness reduction, % 6010	Anisotropy % 6012
Before	57.8	.71	44	43	46	.93
16 % Expan.	74.4	.84	16	38	42	.87
24 % Expan	79.8	.86	20	36	42	.81
Changes, %	38	-21	55	16	9	13

FIGURE 60

6100

Tensile Characteristics before and after Mechanical Expansion



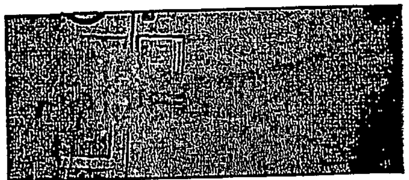
JFE, option B (#2) 16 %

	6102 Yield ksi	6104 Yield ratio	6106 Elongation %	6108 Width reduction %	6110 Wall thickness reduction, %	6112 Anisotropy %
Before	56.4	.66	20	-39	-45	.83
After	74.8	.83	14	33	41	.75
Change %	33	26	30	15	9	10

FIGURE 61

Tensile Characteristics before and after Mechanical Expansion

6200



JFE, option B (#2) 24 %

	Yield ksi (6202)	Yield ratio (6204)	Elongation % (6206)	Width reduction % (6208)	Wall thickness reduction, % (6210)	Anisotropy % (6212)
Before	56.4	.66	20	-39	-45	.83
After	79.6	.84	12	31	38	.79
Change %	41	27	40	21	16	5

FIGURE 62

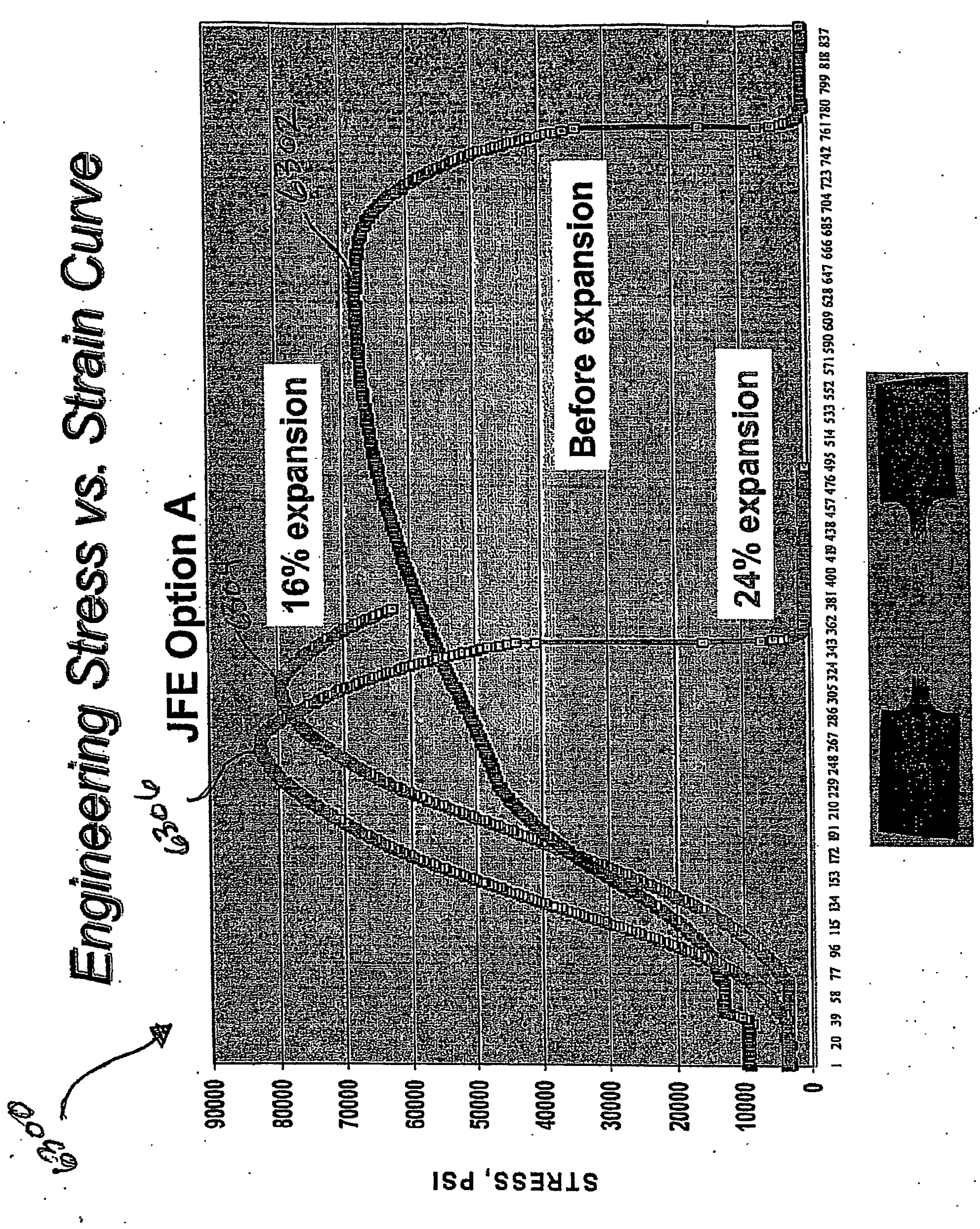

6300
Engineering Stress vs. Strain Curve
JFE Option A
6306
6304
6302
16% expansion
Before expansion
24% expansion
STRESS, PSI
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1 20 39 58 77 96 115 134 153 172 191 210 229 248 267 286 305 324 343 362 381 400 419 438 457 476 495 514 533 552 571 590 609 628 647 666 685 704 723 742 761 780 799 818 837

FIGURE 63

6400

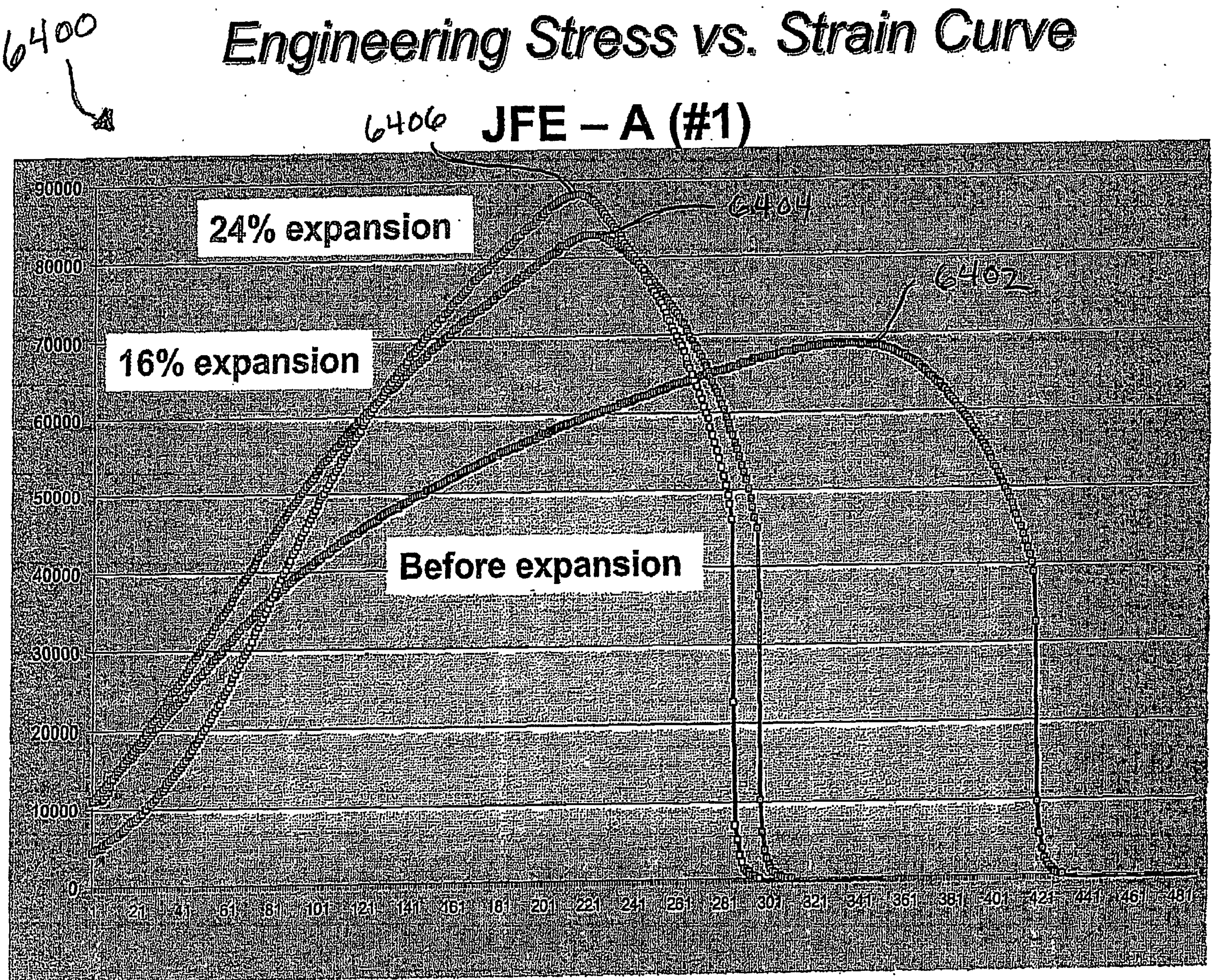


FIGURE 64

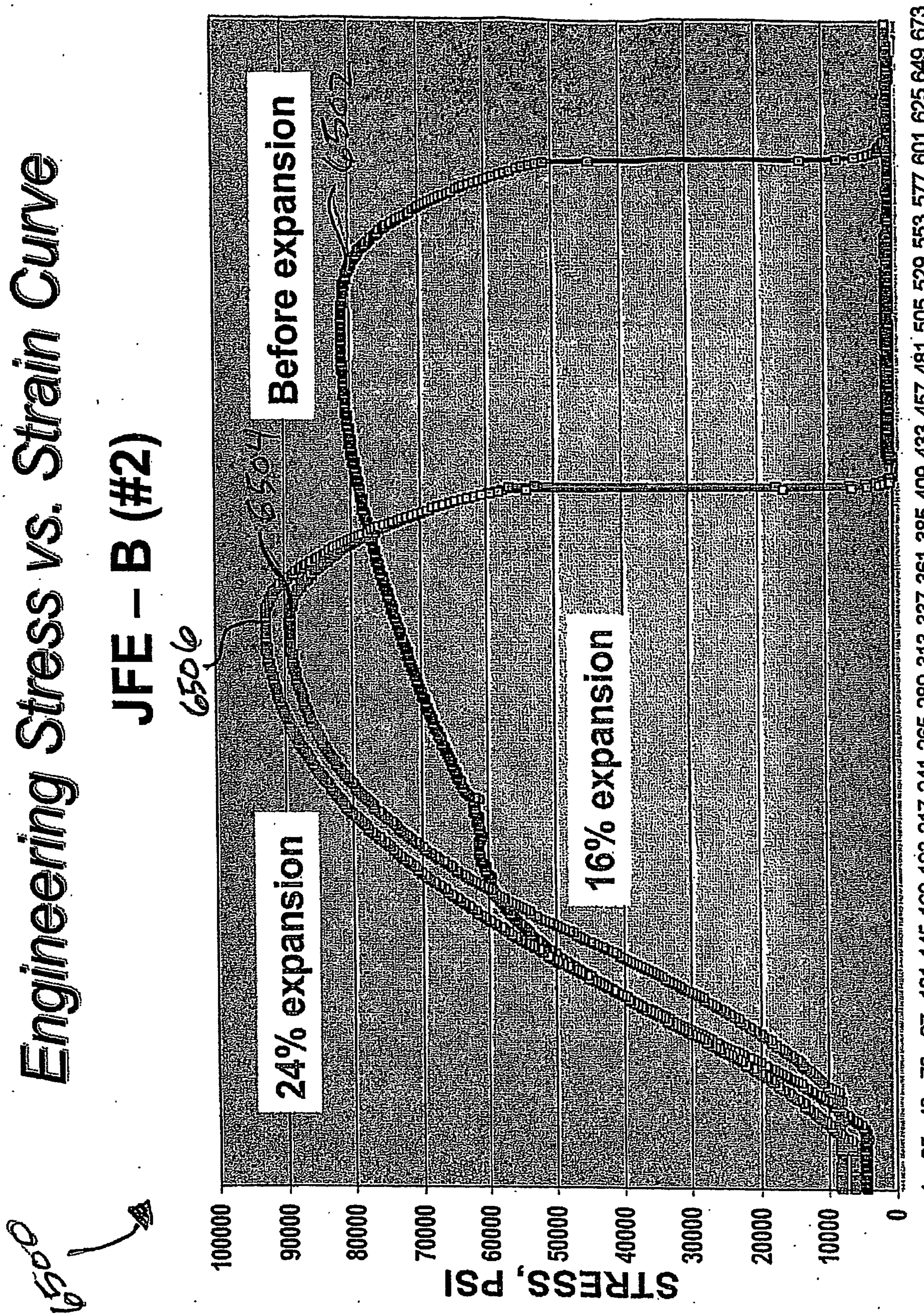

6500
Engineering Stress vs. Strain Curve
JFE – B (#2)
STRESS, PSI
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1 25 49 73 97 121 145 169 193 217 241 265 289 313 337 361 385 409 433 457 481 505 529 553 577 601 625 649 673
24% expansion
16% expansion
Before expansion
6502
6504
6506

FIGURE 65

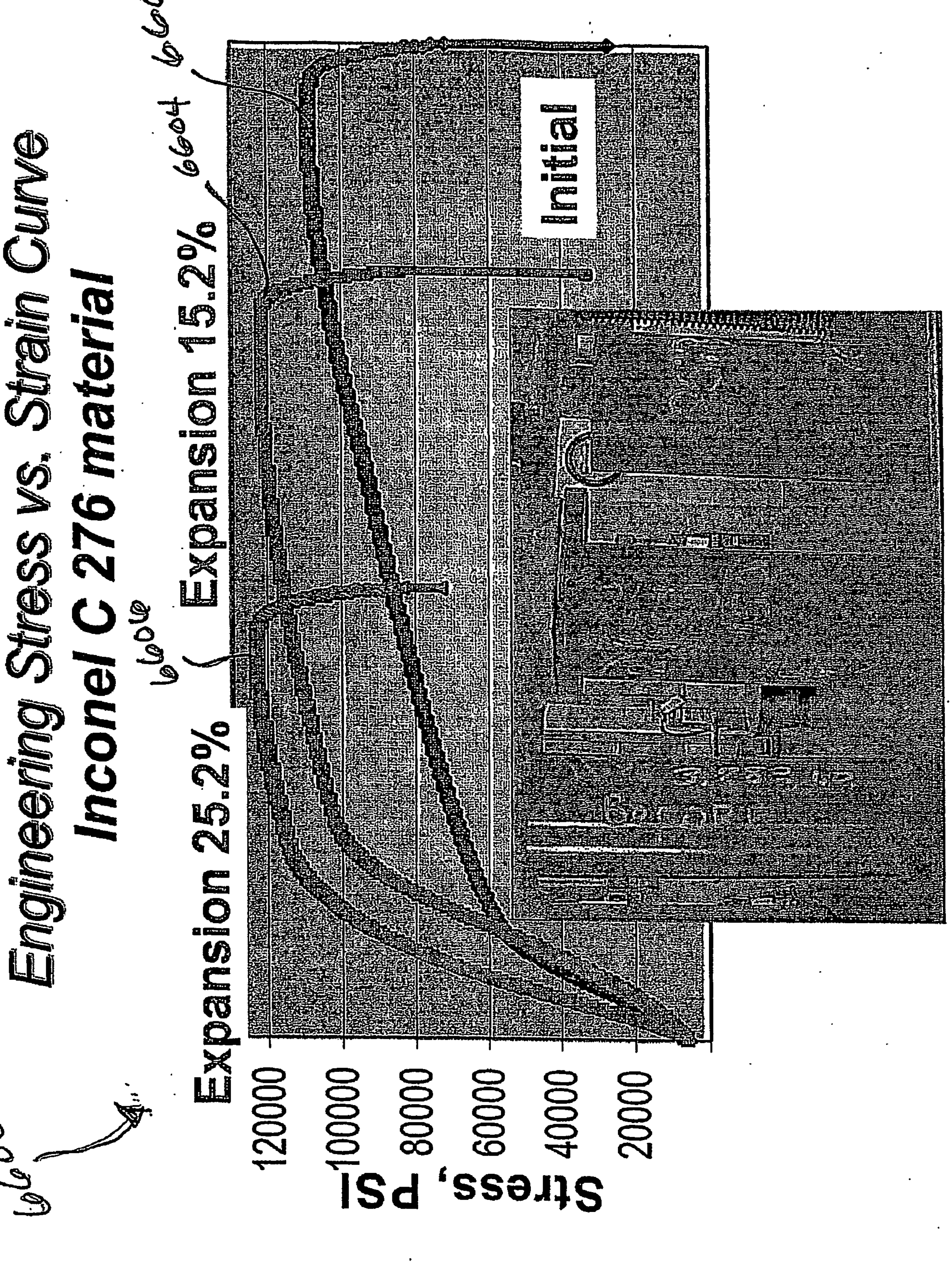

Engineering Stress vs. Strain Curve
Inconel C 276 material
Expansion 25.2%
Expansion 15.2%
Initial
6600
6602
6604
6606
Stress, PSI
120000
100000
80000
60000
40000
20000

FIGURE 66

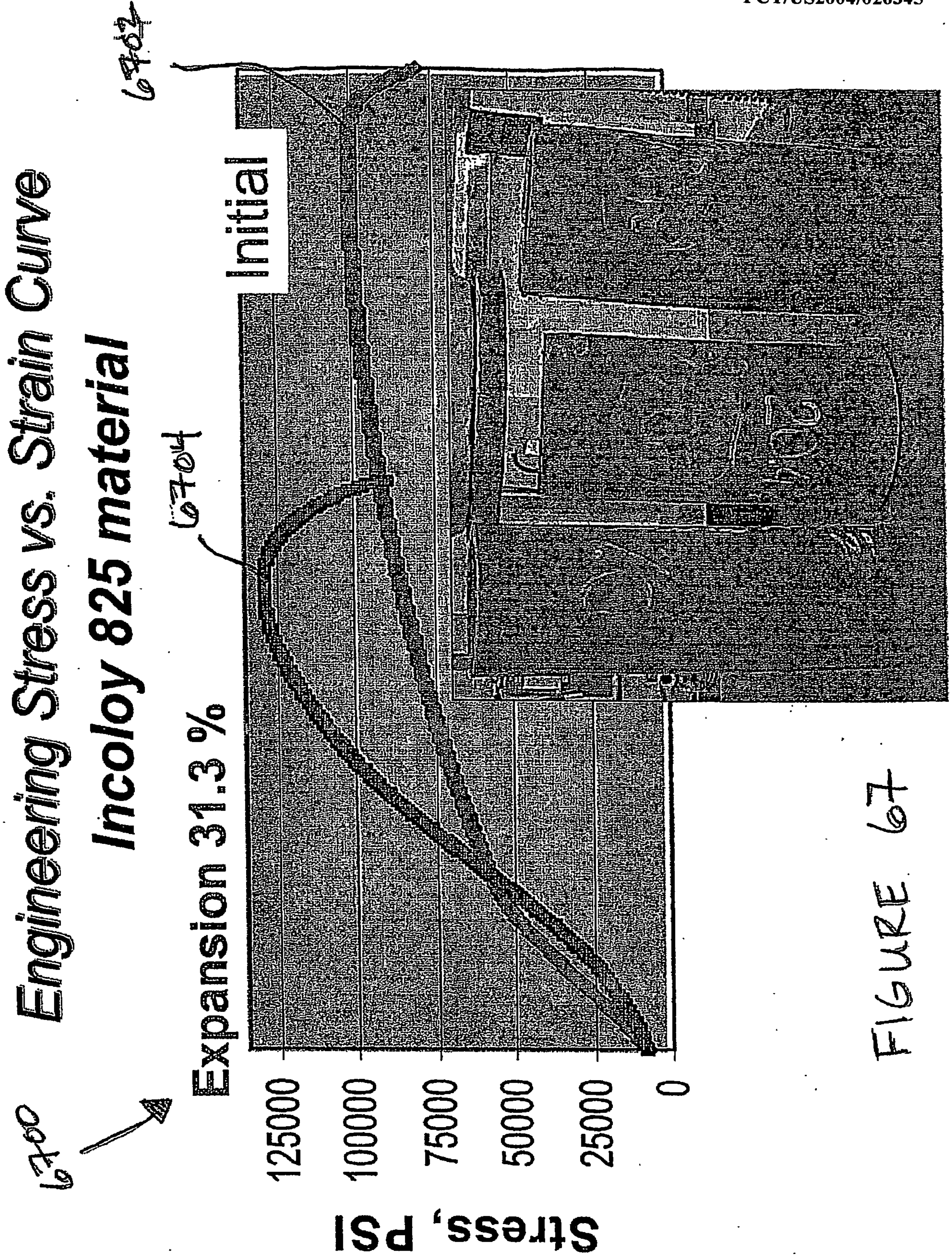
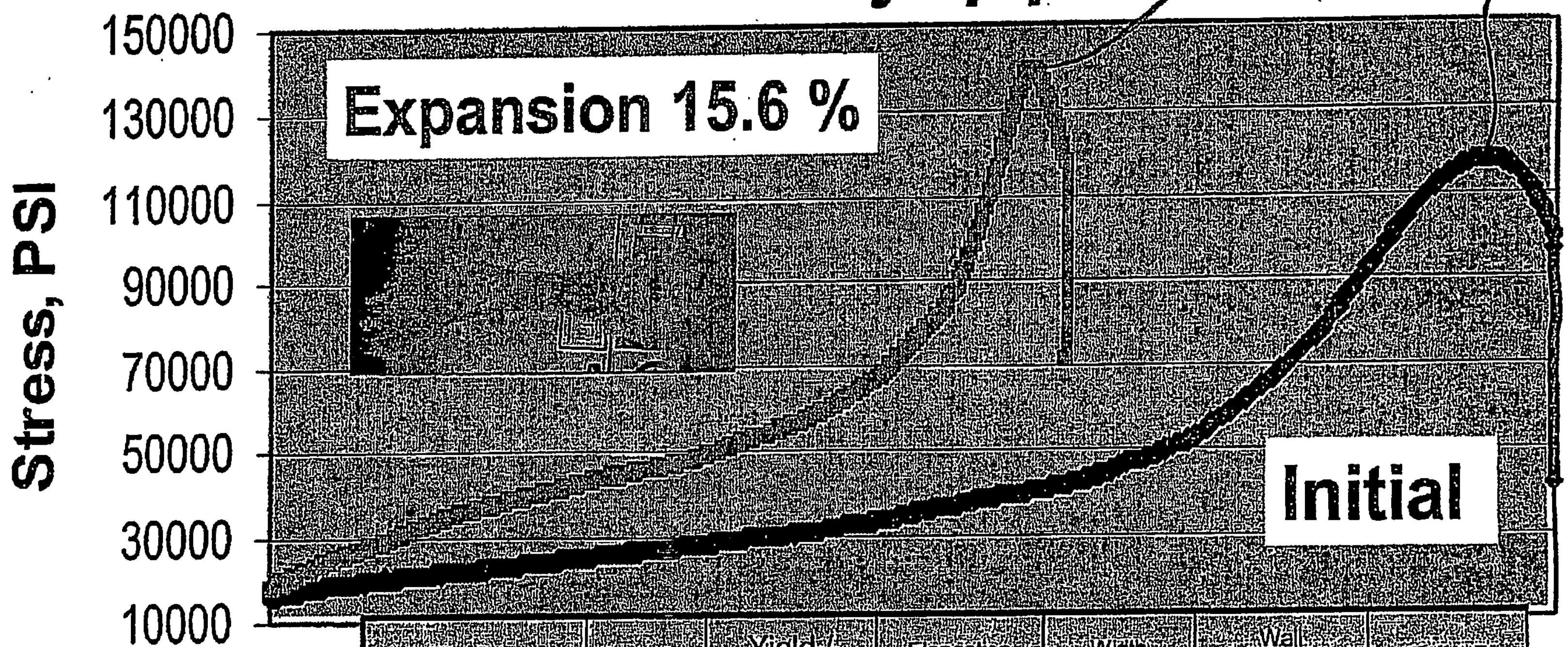

6702
Engineering Stress vs. Strain Curve
Incoloy 825 material
6704
Initial
6700
Expansion 31.3 %
125000
100000
75000
50000
25000
0
Stress, PSI

FIGURE 67

6800

Engineering Stress vs. Strain Curve
"History" pipe

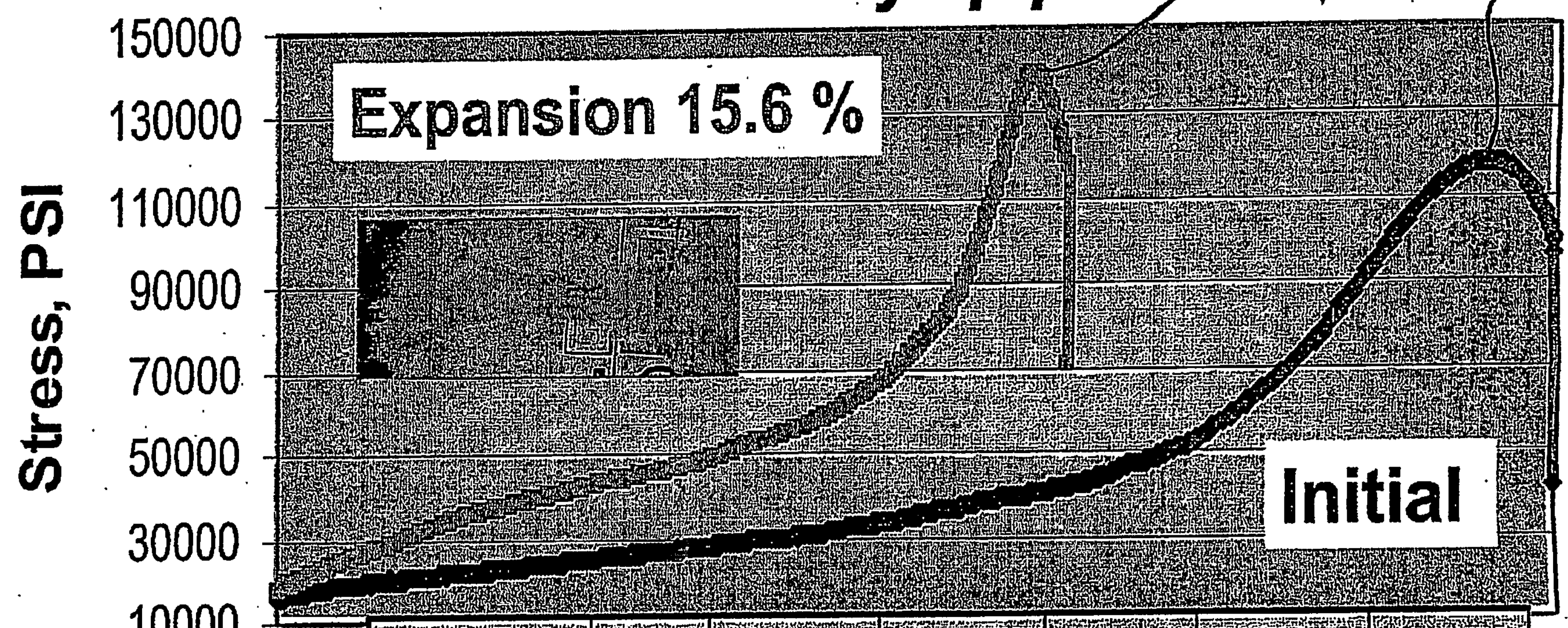


material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction %	Wall thickness Reduction, %	Anisotropy
target	76.8	0.82	16	32	45	0.65
History	50.7	0.44	12	18	15	1.24

FIGURE 68a

6800

Engineering Stress vs. Strain Curve
"History" pipe



6806

material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction, %	Wall thickness Reduction, %	Anisotropy
target	76.8	0.82	16	32	45	0.65
History	50.7	0.44	12	18	15	1.24

FIGURE 68b

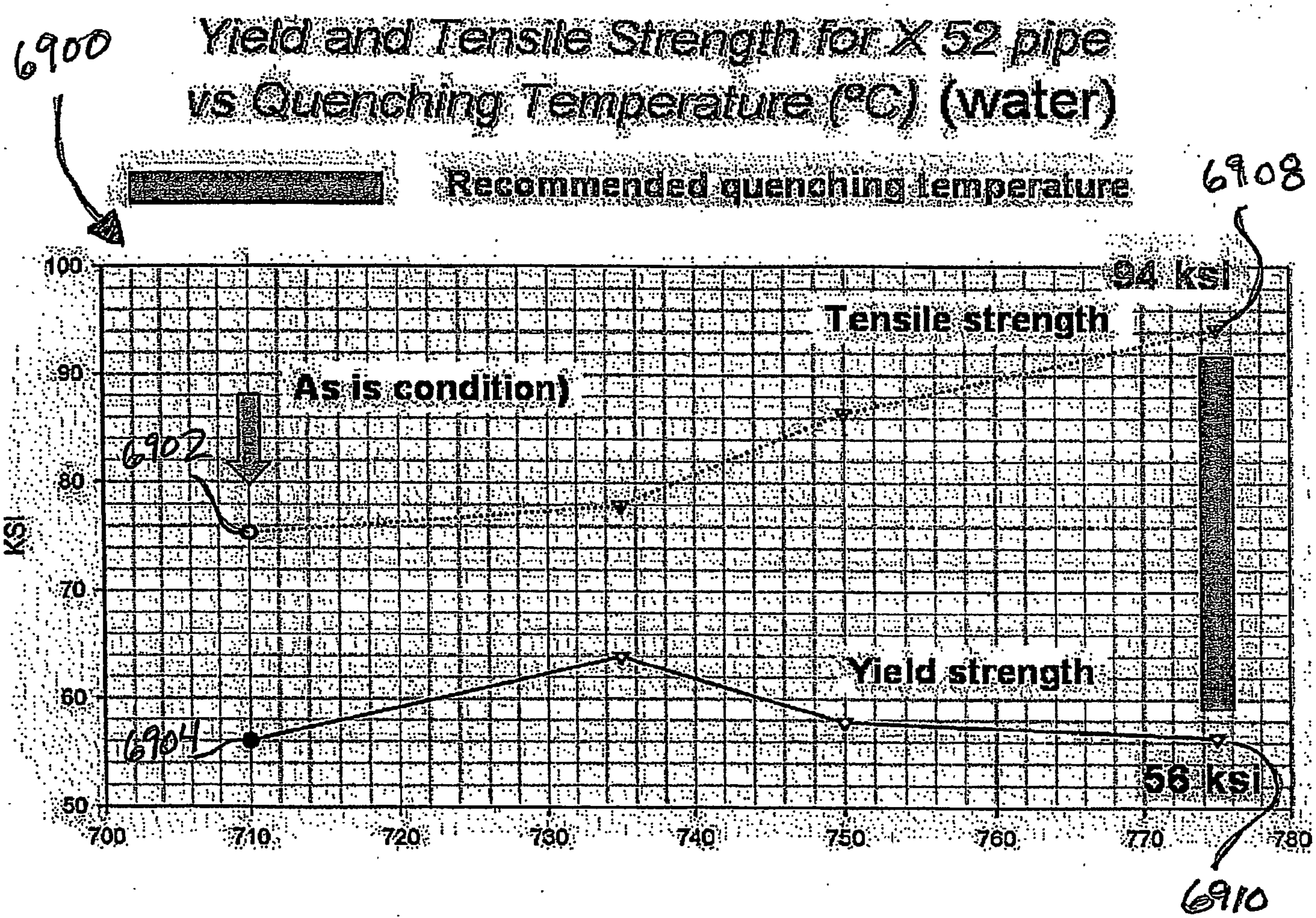

6900
Yield and Tensile Strength for X 52 pipe
vs Quenching Temperature (°C) (water)
Recommended quenching temperature
6908
94 ksi
Tensile strength
As is condition)
6902
6904
Yield strength
56 ksi
6910
KSI
100
90
80
70
60
50
700
710
720
730
740
750
760
770
780

FIGURE 69

7000

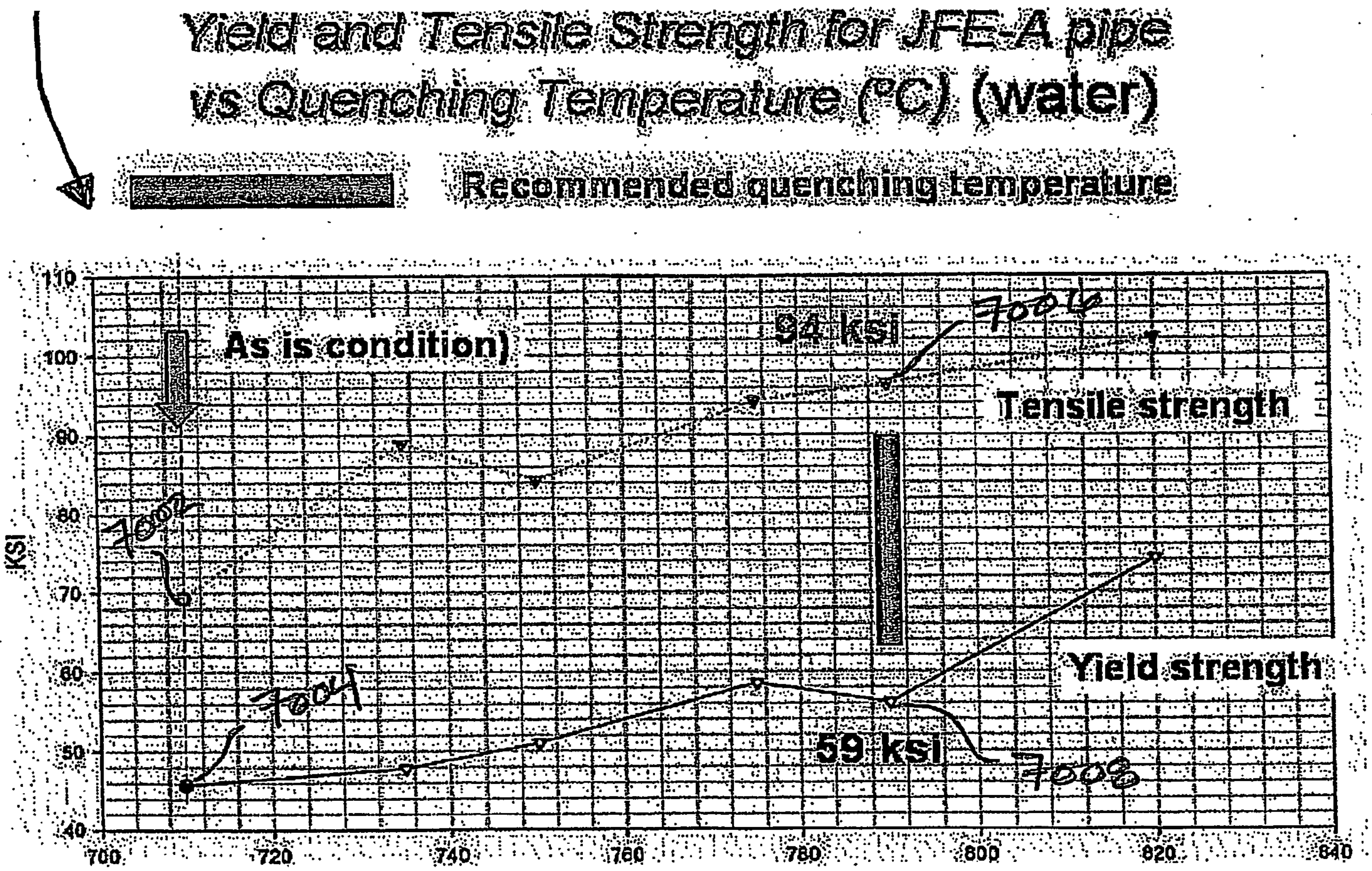


FIGURE 70

7100

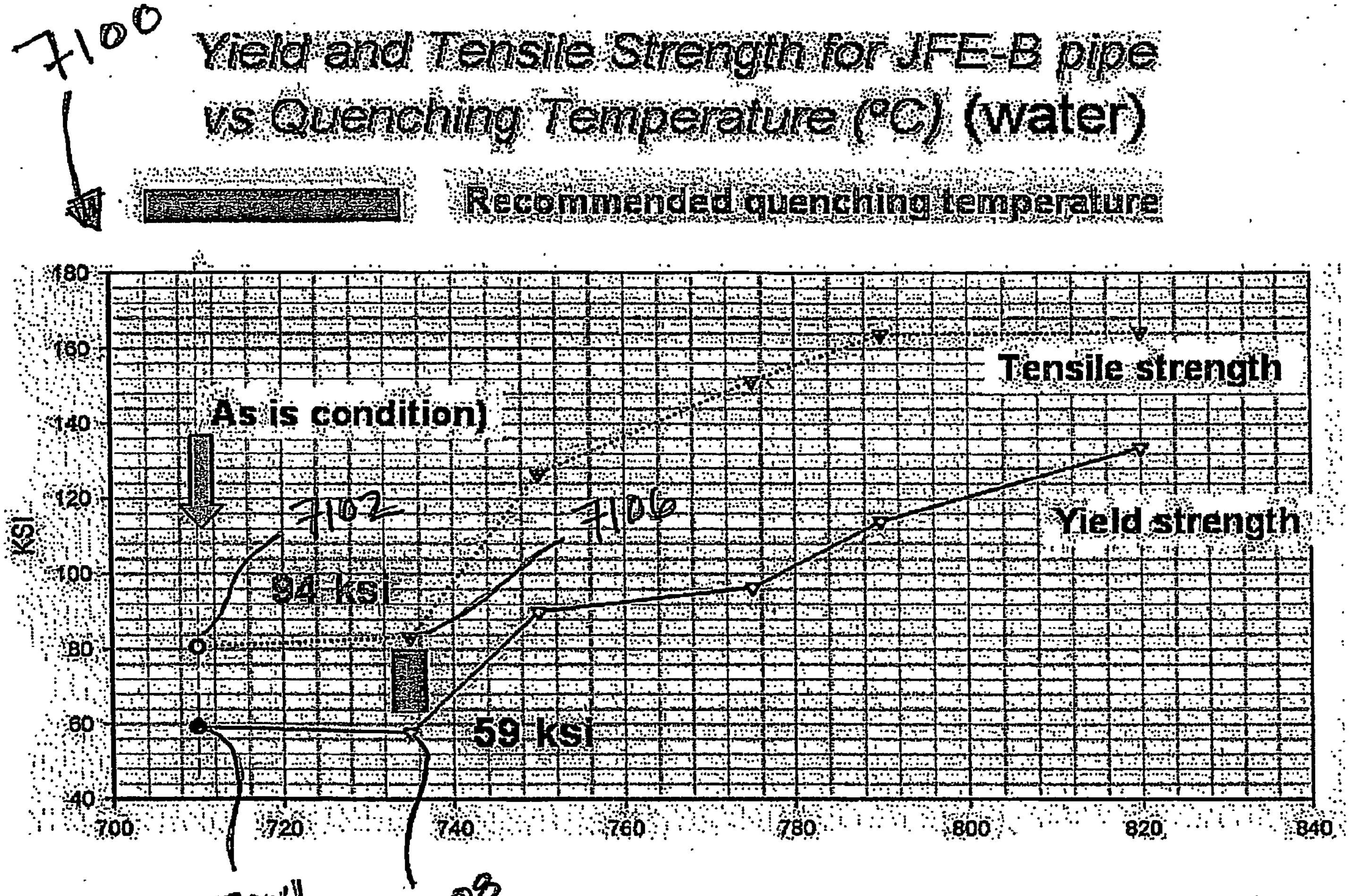
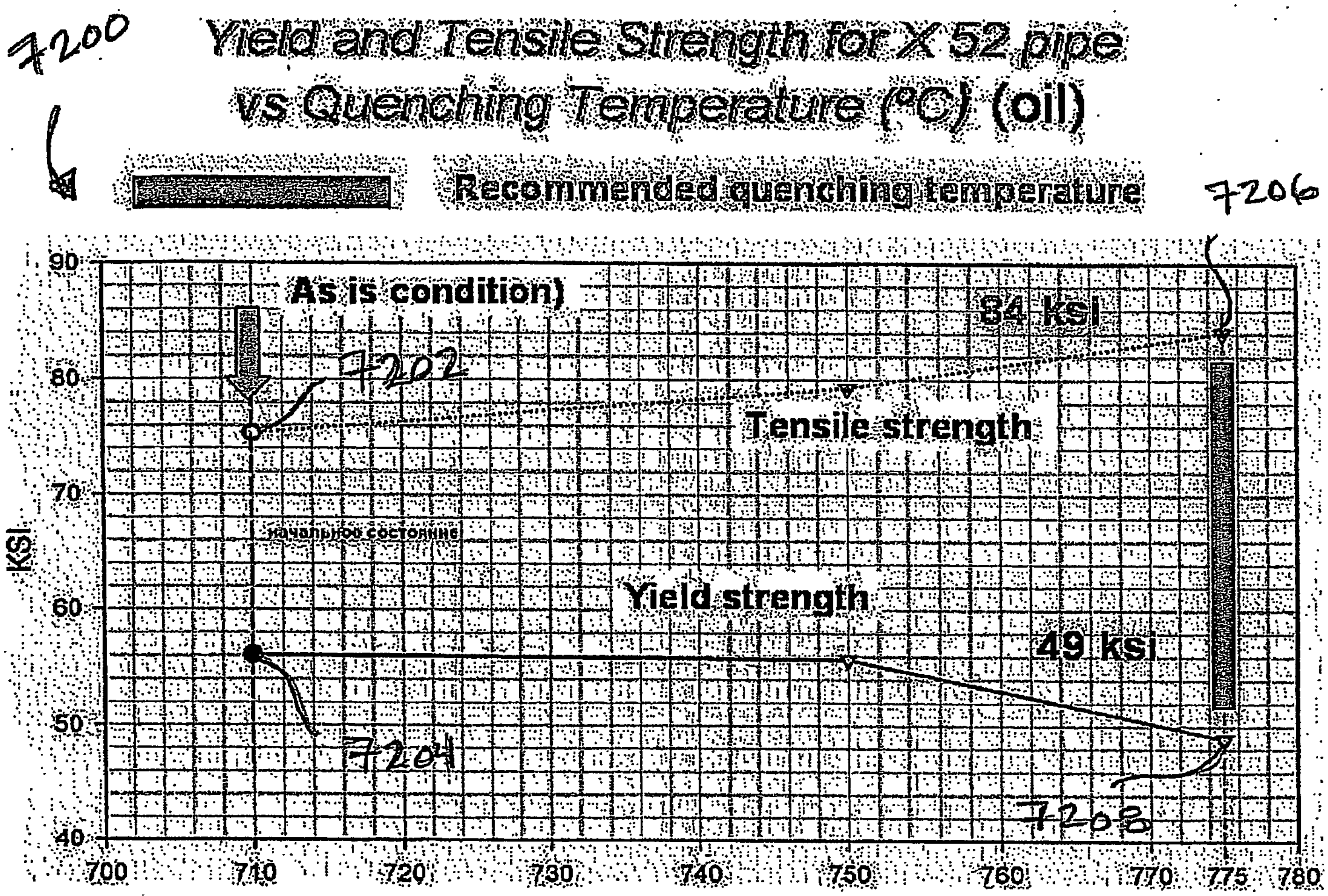


FIGURE 71



7200
Yield and Tensile Strength for X 52 pipe
vs Quenching Temperature (°C) (oil)
Recommended quenching temperature
7206
As is condition)
84 ksi
7202
Tensile strength
начальное состояние
KSI
Yield strength
49 ksi
7204
7208
90
80
70
60
50
40
700
710
720
730
740
750
760
770
775
780

FIGURE 72

7300

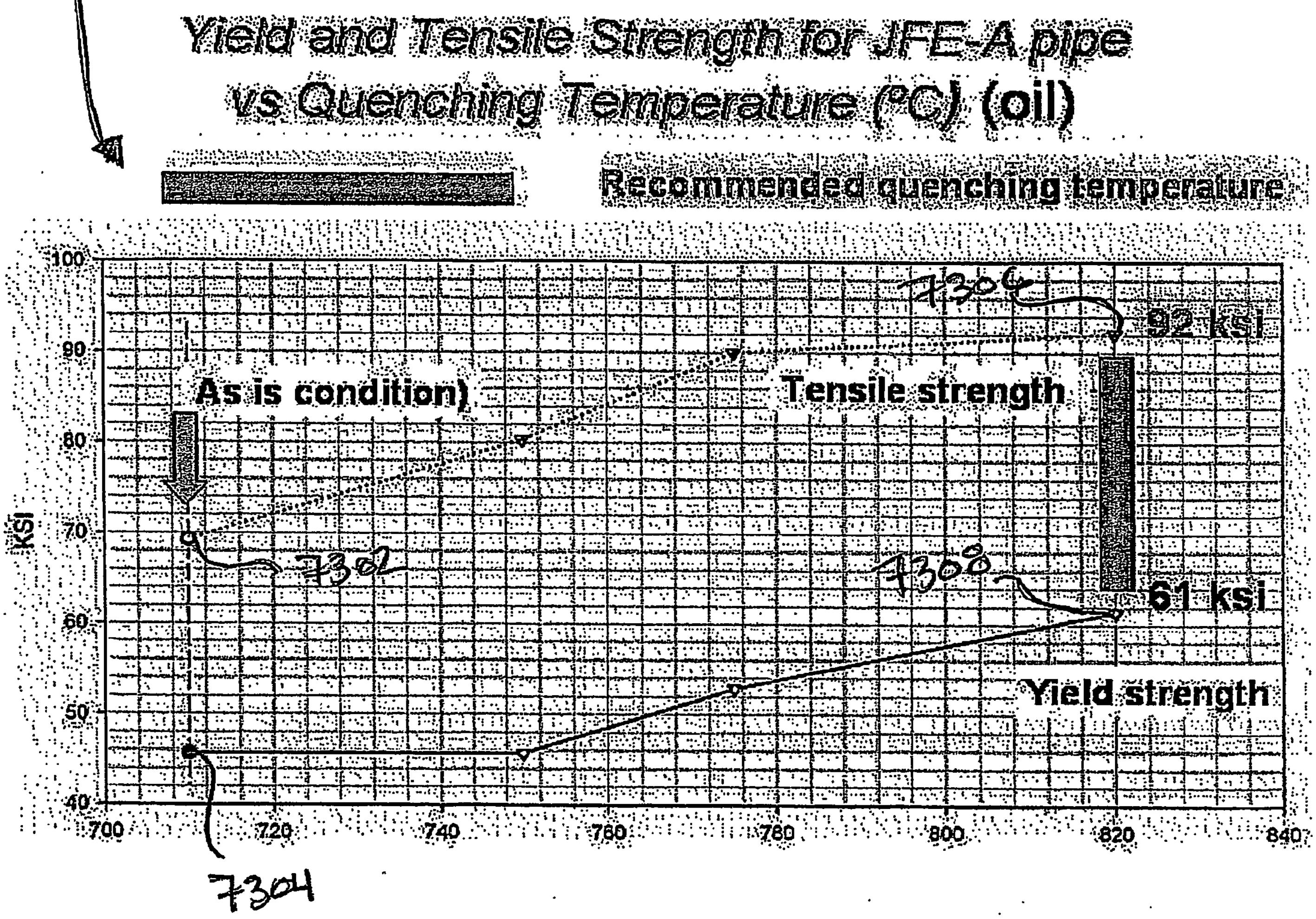


FIGURE 73

7400

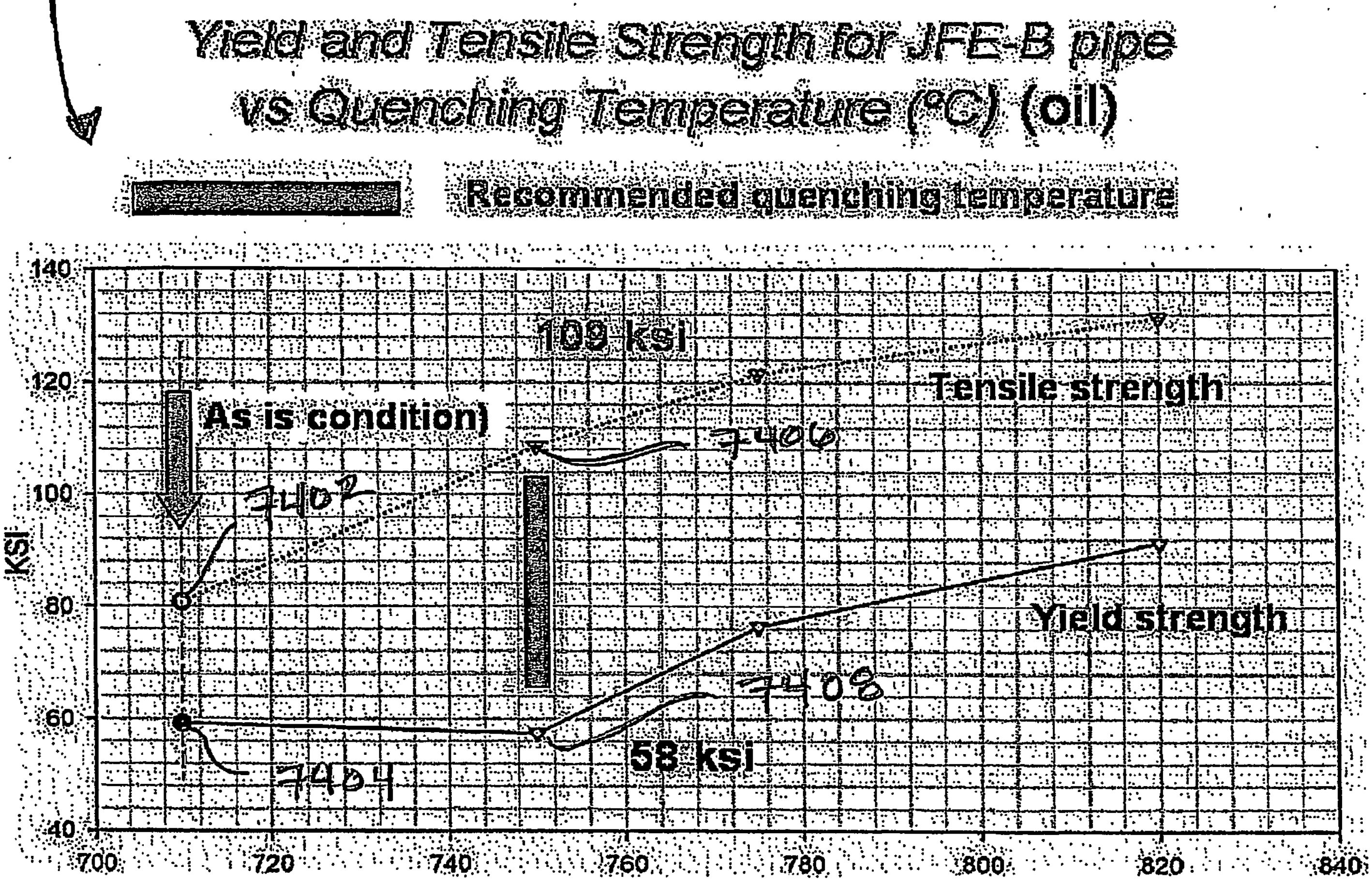
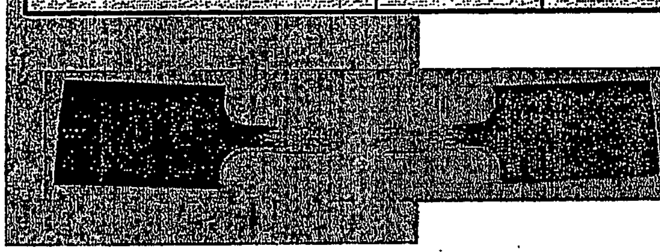


FIGURE 74

Stress-Strain Property of the Target vs. Quench & Temper N Steel Pipes*

material	Yield, ksi 7506	Yield / Tensile ratio 7508	Elongation Longitudinal % 7510	Width Reduction,% 7512	Wall thickness Reduction, % 7514	Anisotropy 7516
target 7500	80.18	0.857	14.75 *	38.3	43.0	0.868
7502 Quench & temper pipe-1	81.25	0.829	14.88 *	37.8	43.25	0.830
7504 Quench & temper pipe-2	78.77	0.822	15.90 *	44.0	43.33	1.03



*An average from 4 measurements

* 5 " base line

FIGURE 75

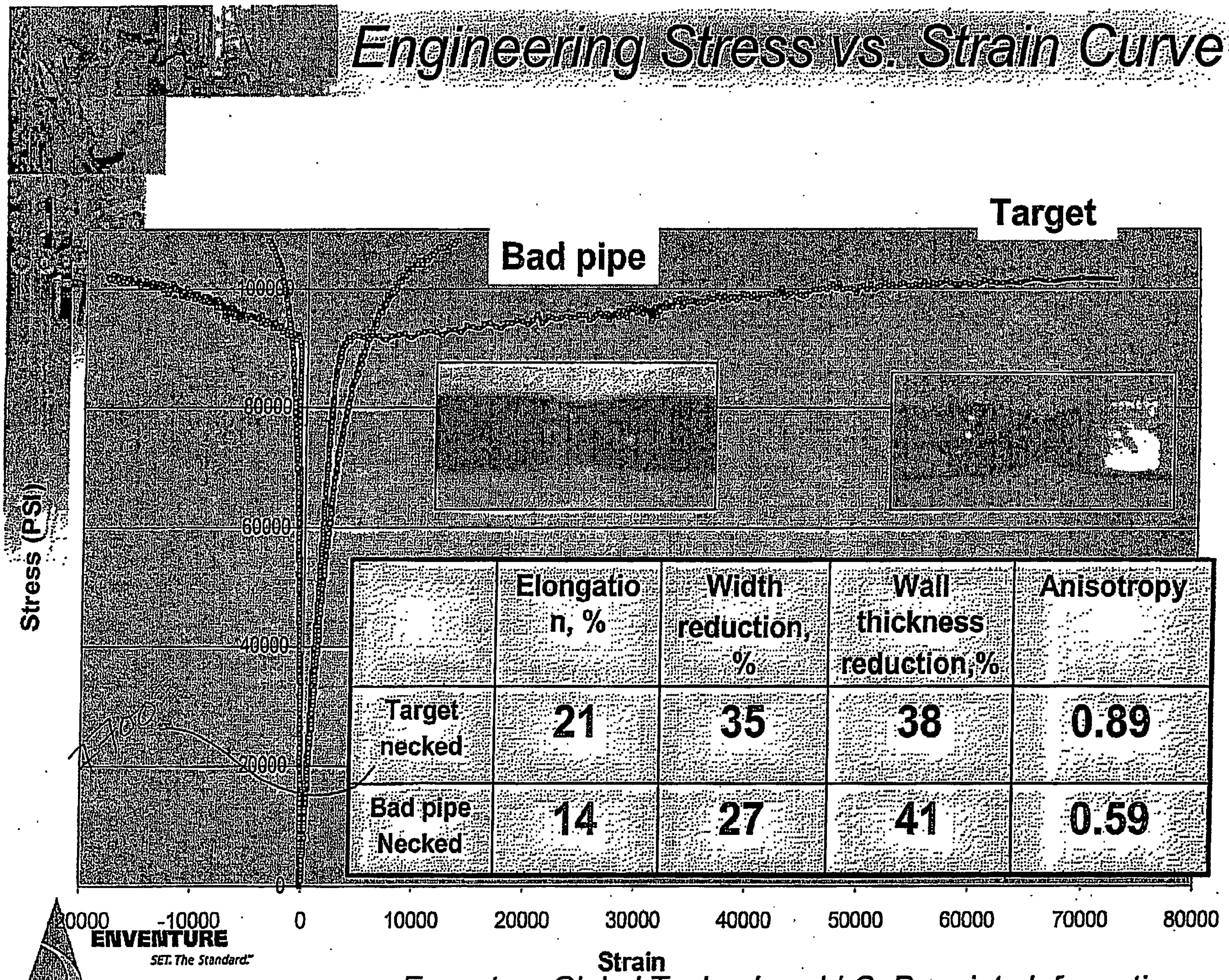
Stress-Strain Property of the Target vs. Quench & Temper Nippon Steel Pipes*

material	Yield ksi 7504	Yield / Tensile ratio 7506	Elongation Longitudinal % 7508	Width Reduction, % 7510	Wall thickness Reduction, % 7512	Anisotropy 7514
target 7500	80.18	0.857	14.75*	38.3	43.0	0.868
Quench & temper pipe 7502	80.19	0.826	15.25*	40.4	43.3	0.915

*An average from 4 (target) and 8 (quench & temper measurements

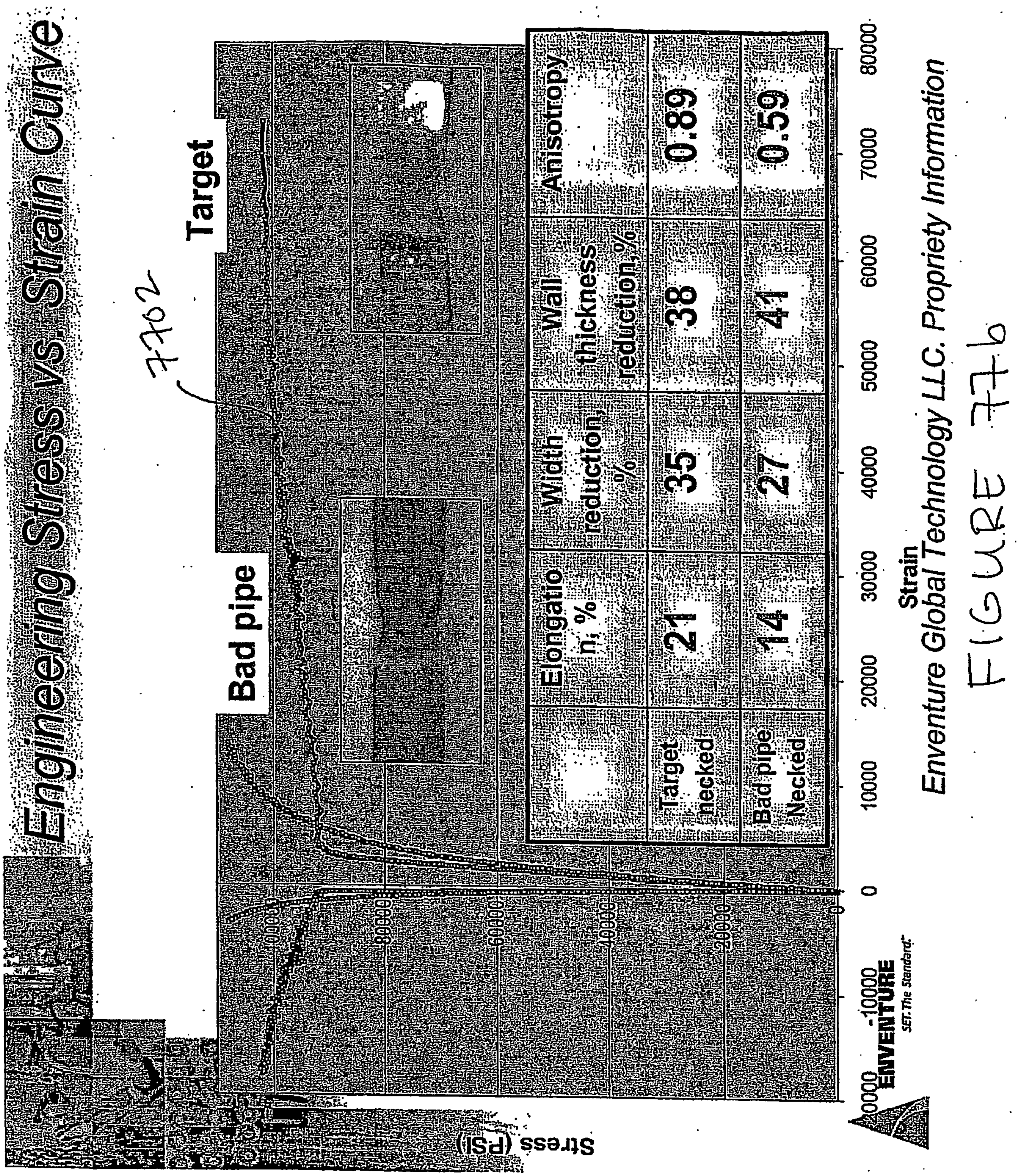
*5 " base line

FIGURE 76



	Elongation, %	Width reduction, %	Wall thickness reduction,%	Anisotropy
Target necked	21	35	38	0.89
Bad pipe Necked	14	27	41	0.59

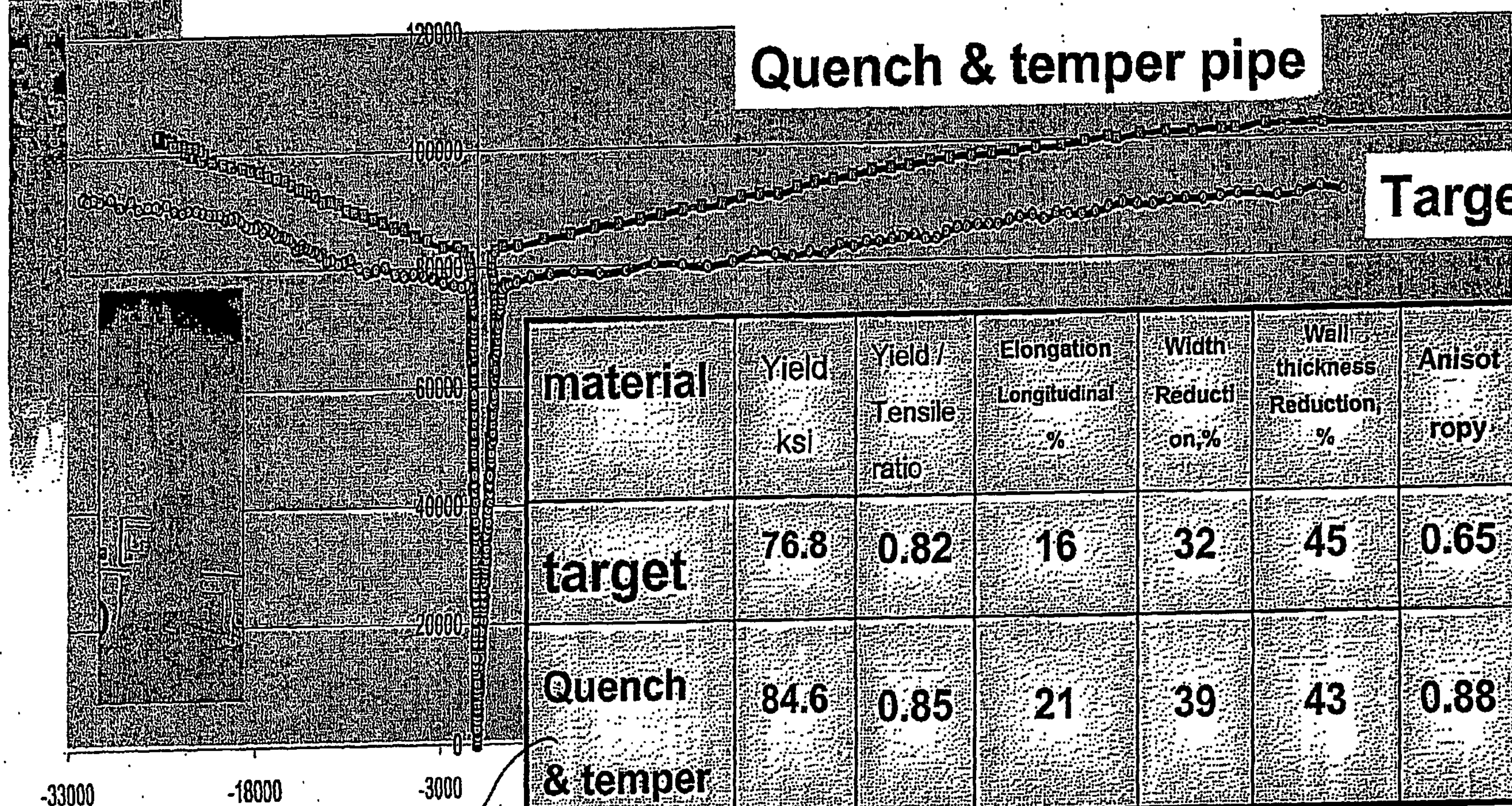
FIGURE 77a



	Elongatio n, %	Width reduction, %	Wall thickness reduction,%	Anisotropy
Target necked	21	35	38	0.89
Bad pipe Necked	14	27	41	0.59

FIGURE 77b

Engineering Stress vs. Strain Curve



material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction,%	Wall thickness Reduction, %	Anisotropy
target	76.8	0.82	16	32	45	0.65
Quench & temper	84.6	0.85	21	39	43	0.88

FIGURE 78a

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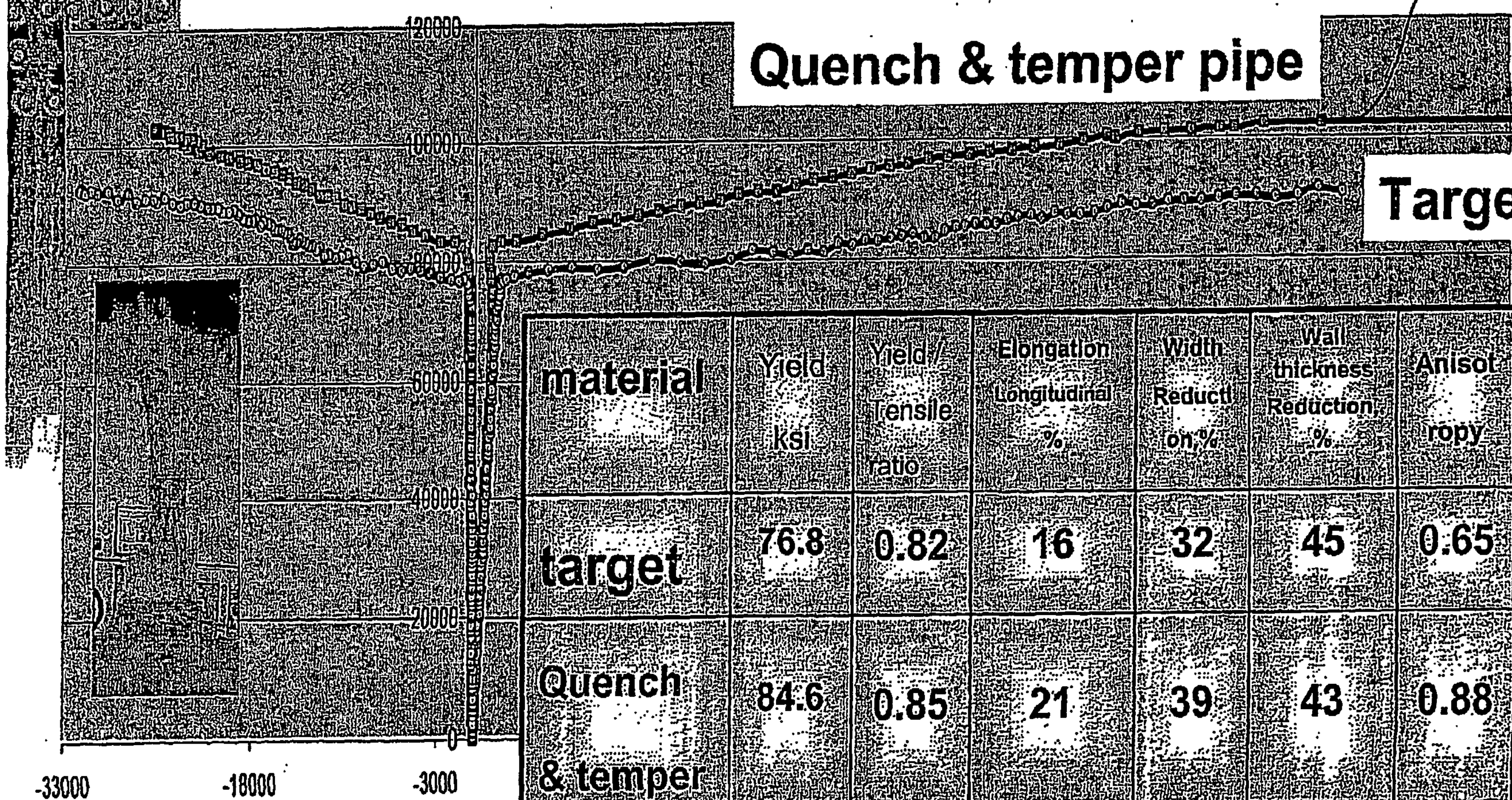
Enventure Global Technology LLC. Propriety Information

Engineering Stress vs. Strain Curve



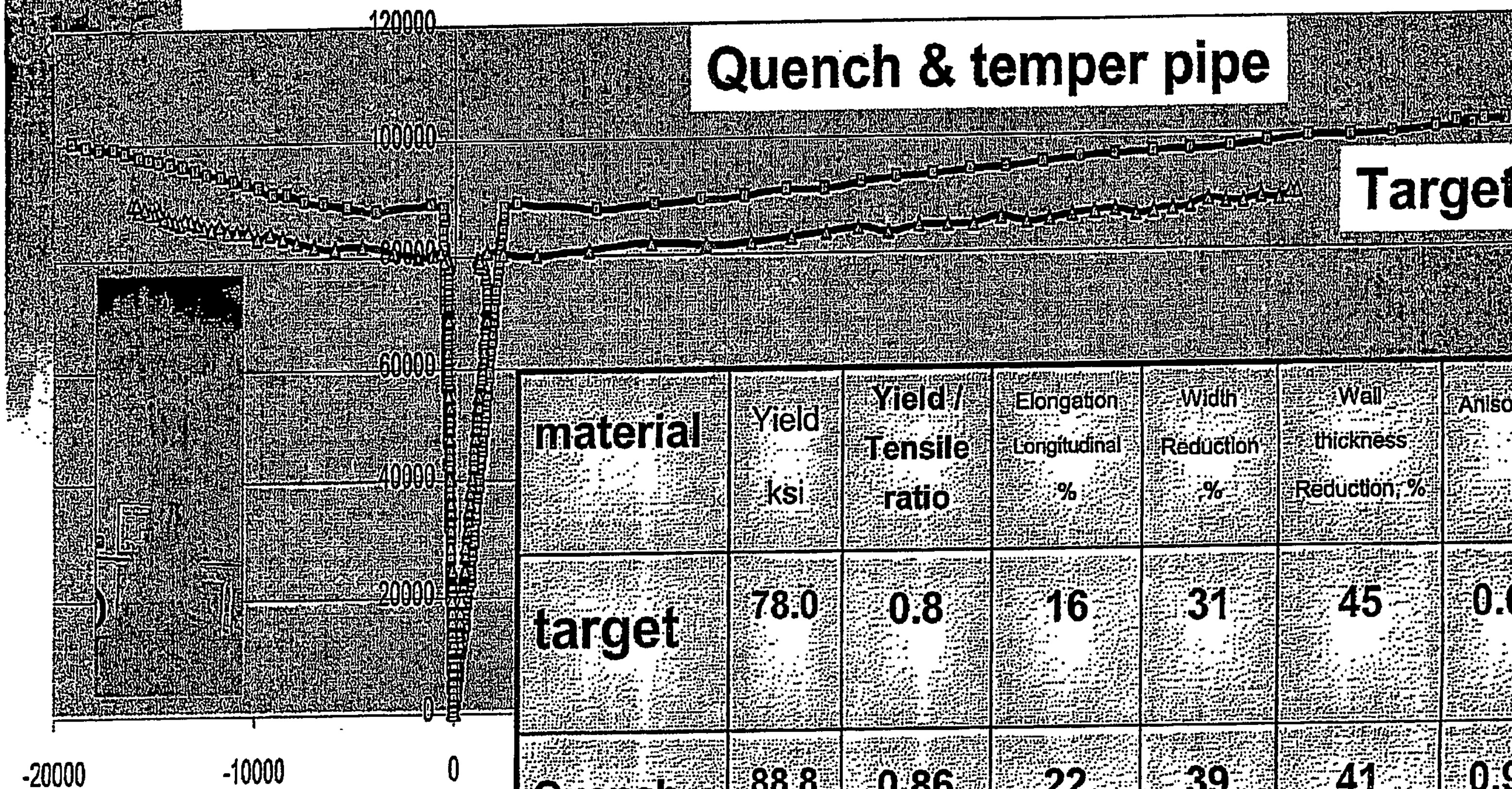
material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction,%	Wall thickness Reduction, %	Anisotropy
target	76.8	0.82	16	32	45	0.65
Quench & temper	84.6	0.85	21	39	43	0.88

FIGURE 78b

ENVENTURE SET. The Standard.

Enventure Global Technology LLC. Propriety Information

Engineering Stress vs. Strain Curve



material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction %	Wall thickness Reduction, %	Anisotropy
target	78.0	0.8	16	31	45	0.63
Quench & temper	88.8	0.86	22	39	41	0.93

7900

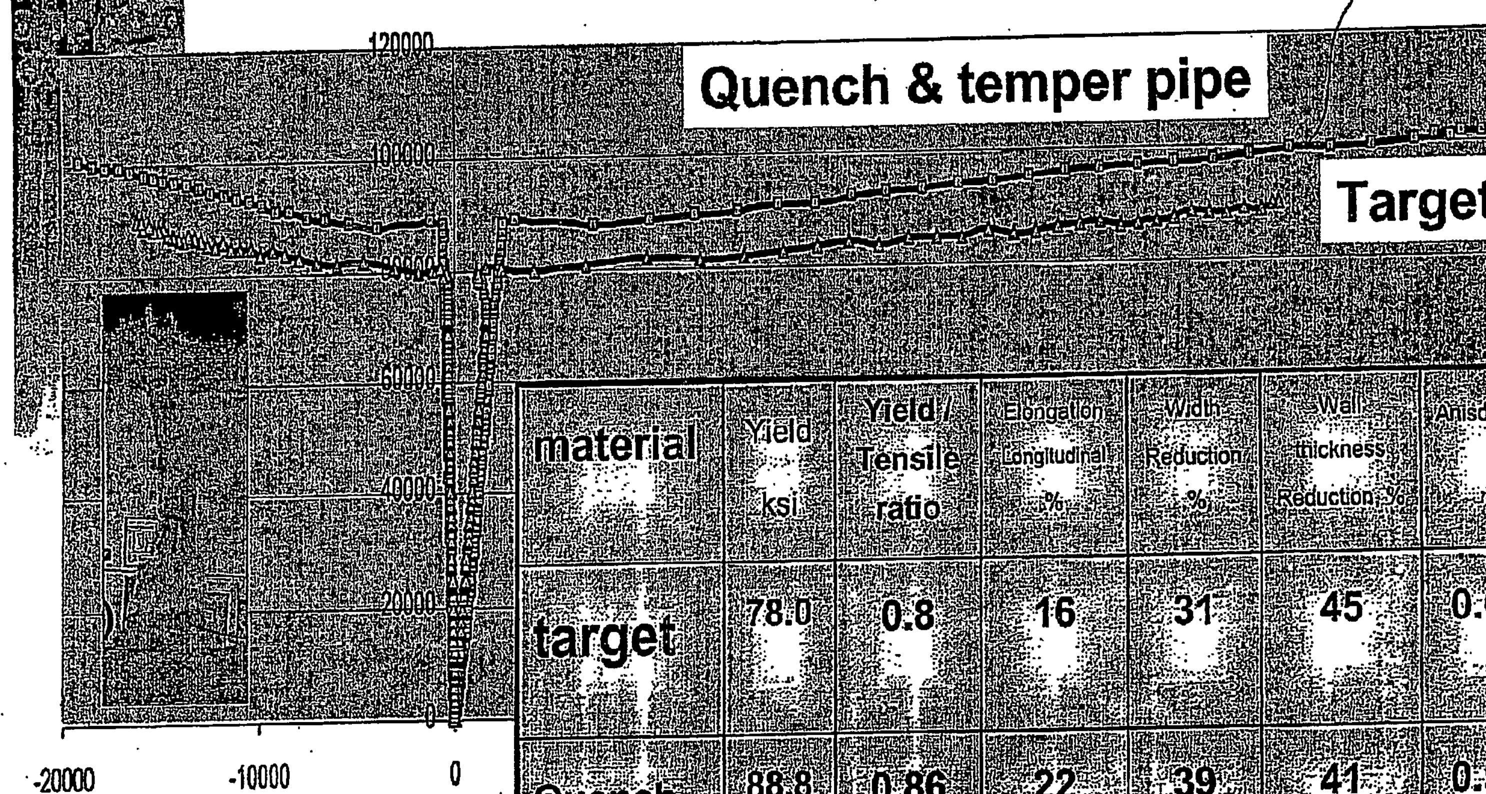
ENVENTURE SET. The Standard™

Enventure Global Technology LLC. Propriety Information

FIGURE 79a

Engineering Stress vs. Strain Curve

7902



material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction %	Wall thickness Reduction %	Anisotropy
target	78.0	0.8	16	31	45	0.63
Quench & temper	88.8	0.86	22	39	41	0.93

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FIGURE 79b

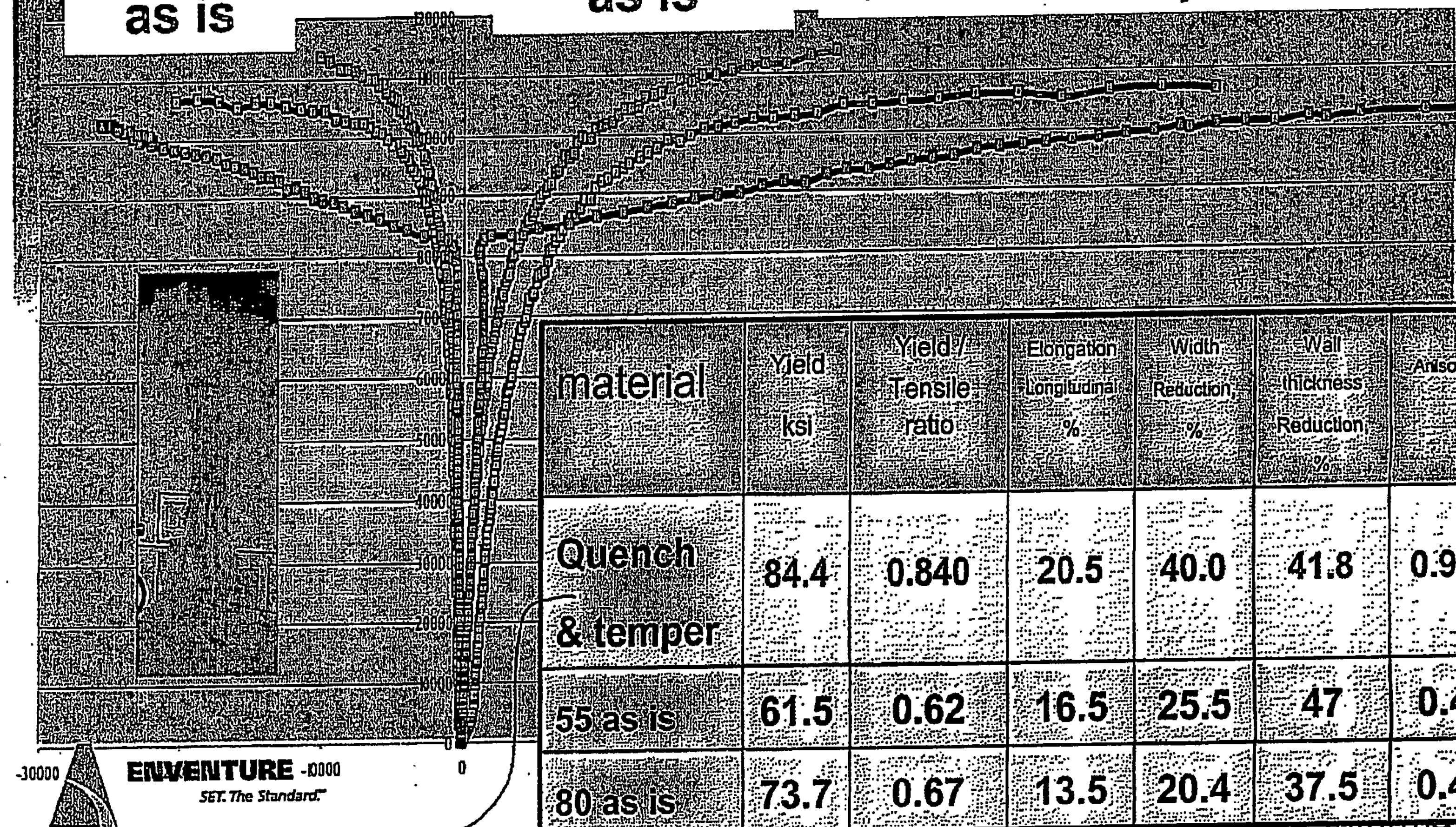
Engineering Stress vs. Strain Curve

(as received pipe vs. heat treated)

Pipe 7 " as is

Pipe 9 5/8 " as is

Quench & temper 9 5/8 'pipe



material	Yield ksi	Yield / Tensile ratio	Elongation Longitudinal %	Width Reduction %	Wall thickness Reduction %	Anisotropy
Quench & temper	84.4	0.840	20.5	40.0	41.8	0.935
55 as is	61.5	0.62	16.5	25.5	47	0.46
80 as is	73.7	0.67	13.5	20.4	37.5	0.48

8000

FIGURE 80a

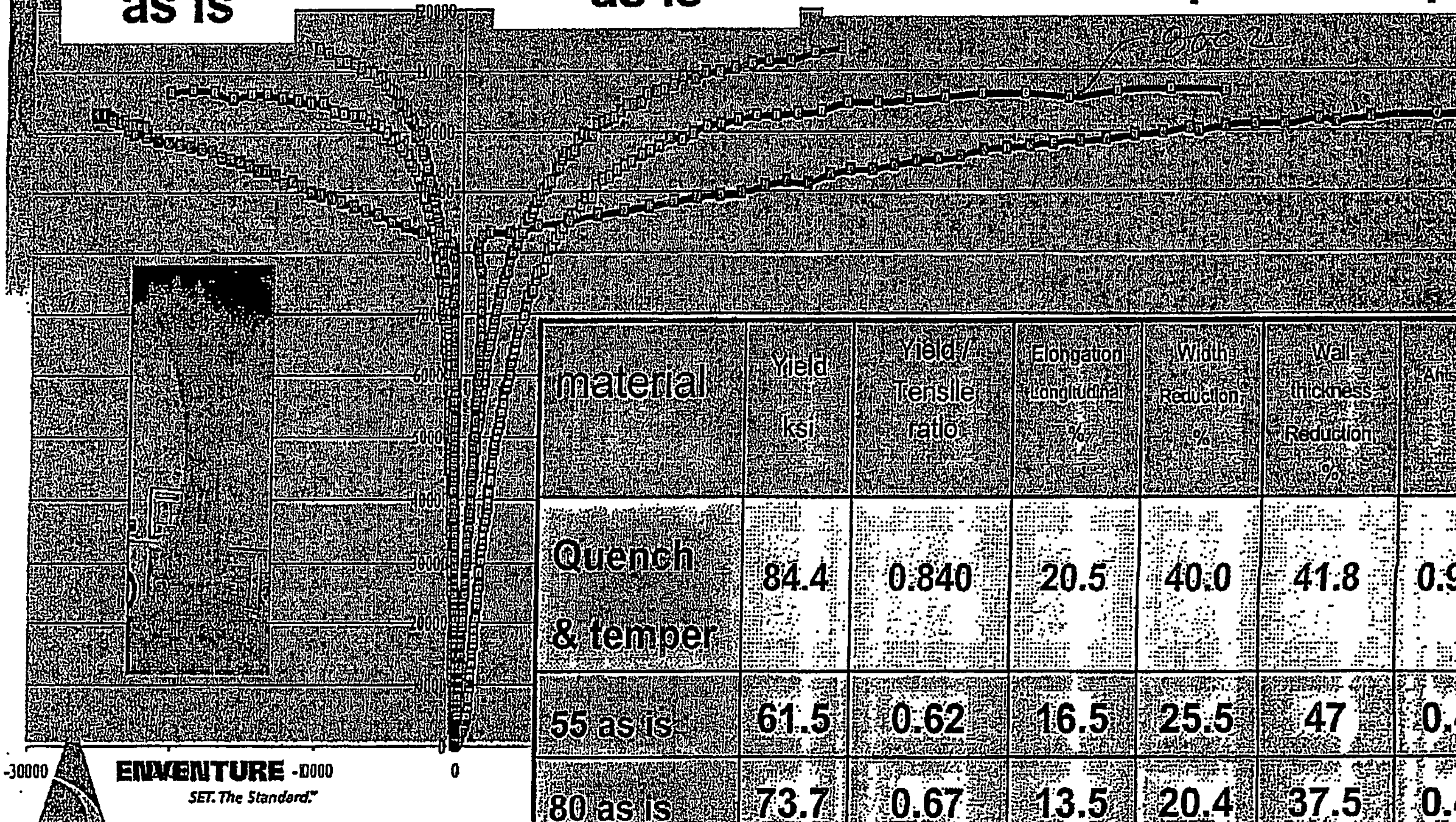
Engineering Stress vs. Strain Curve

(as received pipe vs. heat treated)

Pipe 7 " as is

Pipe 9 5/8 " as is

Quench & temper 9 5/8 'pipe



material	Yield ksi	Yield/ Tensile ratio	Elongation Longitudinal %	Width Reduction %	Wall thickness Reduction %	Anisotropy
Quench & temper	84.4	0.840	20.5	40.0	41.8	0.935
55 as is	61.5	0.62	16.5	25.5	47	0.46
80 as is	73.7	0.67	13.5	20.4	37.5	0.48

FIGURE 80b

Bone Sample Formability Judgment

Sample	Yield	Y/U	Elongation	Width reduction	Wall thickness reduction	Anisotropy	Technology
8100							
40045	80.1	.72	35	35	33	.92	Hot stretch, reduced (1950°), rotary straightened
8102 4-100	89.7	.88	25	22	20	1.1	Normalized (1850°), cold drawn, annealed (1050°), rotary straightened
8104 5-790	88.1	.87	16	24	30	.76	Hot stretch, reduced (1950°), cold drawn, annealed, rotary straightened
8106 40513	47.7	.73	38	43	49	.83	Hot stretch, reduced (1850°), rotary straightened
8108 40514	45.5	.69	40	50	53	.93	Hot reduced (1850°), cold sized, rotary straightened
8110 40241	52.7	.85	49	49	46	1.1	Hot stretch, reduced (1850°), rotary straightened

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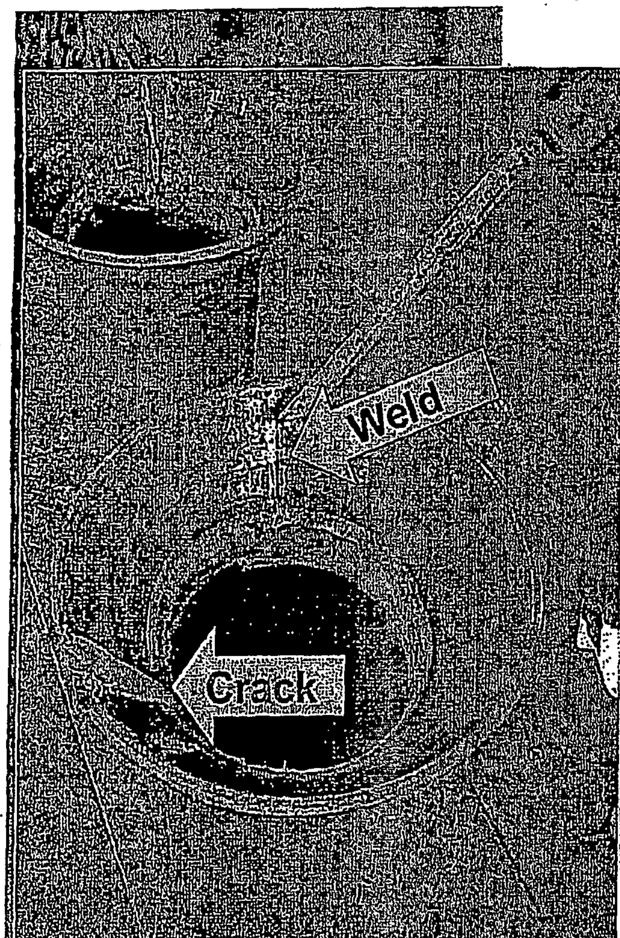
FIGURE 81

Absorbed Energy and Flare Expansion Testing



material	Absorbed energy^ Longitudinal	Transverse	Weld	Flare expansion %
target	80	60	60	45
Quench & temper 8200	125	59	176	42
Quench & temper 8202	145	59	174	52
As is, 55 grade	100	40	70	32*
As is, 80 grade	50	30	4	30*

Quench& temper pipe, failure of pipe @ expansion load of 800000 & 1,200000 Lbs
*As received pipe, cracking in weld area
^ Measured at -4° F (-20° C)

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FIGURE 82